The Engineer

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THE ENGINEER

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REORGANISING ELECTRICITY SUPPLY

When, in 1954, some six years after the industry had been nationalised, the Government set up a committee under the chairmanship of Sir Edwin Herbert "to inquire into the organisation and efficiency of the electricity supply industry in England and Wales in the light of its working under the Electricity Act, 1947, and to make recommendations," it was already obvious that it was hankering after some change in the organisation that the Socialist Government had created. But when the report of the committee was published earlier this year so many of its recommendations were open to adverse criticism that some doubt necessarily remained whether, in fact, the Government would act. The publication last week of an Electricity Bill accompanied by an explanatory White Paper on "Proposals for the Reorganisation of the Electricity Supply Industry" sets such doubts at rest. The Government intends to do for the electricity supply industry what it has already done for the railways. Decentralisation is to be brought about by enlarging the powers of the Area Boards and reducing those of the Central Electricity Authority, the new scheme to come into effect on April 1, 1958.

But the Government, wisely, has not wholly followed the recommendations of the Herbert Committee. That committee—we were critical of the proposal at the time—recommended that there should be a new central authority without executive functions, but with very wide powers of supervision over the operations of Area Boards. The Government, like critics of the report, ourselves included, regards that recommendation as impracticable. It would have conferred on the new central authority, in the Government's opinion, "great power over the industry with little corresponding responsibility." There remained to the Government, therefore, two choices, either to leave the organisation much as it is—after all, though the boards have been critical of the centralisation of control in the authority, it has not done at all badly—or to devise some method of decentralisation different from that recommended by the committee. In fact, the committee, in its deliberations, did discuss, only to reject, a more extreme form of decentralisation than that which it recommended. It was that the central authority should disappear, and that the Area Boards should become autonomous, buying electricity from a new "Generation Board." In essence, that is the organisation which the Government now proposes to set up. There is the difference, however, that there is to be, in addition, a central Electricity Council consisting of the chairman of the independent Area Boards and the chairman and one other member of the Generating Board, presided over by an independent chairman and two deputy-chairmen appointed by the Minister, who would also be responsible for appointing Area and Generation Board chairmen. The council is to be responsible for co-ordinating the work of the boards and it will act as the agent of the boards in raising finance and in the performance of such services as are best performed in common, such as research. It will also take the place of the authority in seeking agreement with trade unions on machinery for negotiating terms and conditions of employment in the industry as a whole. The council will be responsible for advising the Minister on questions affecting the industry as a whole. But the boards will become autonomous bodies responsible for their own finances. The Generating Board and each Area Board will be required to balance its accounts individually. The balance, "taking one year with another," will no longer apply to the industry as a whole, but to each area separately. In fact, the clock is to be put back to a quite considerable extent. A return is to be made to something not unlike the system as it was before the industry was nationalised with the important difference that Area Boards replace the local authorities and private companies that formerly distributed electricity.

There can, we think, be no doubt that the Government's proposals are practicable, and that the industry can be efficiently run under such a system. But whether

it is a better organisation is altogether another matter. Certainly there has been criticism, particularly of the over-centralisation, of the present organisation. But, it seems to us, over-centralisation is the necessary immediate consequence of the nationalisation of an industry. It is necessary to establish within the constituent units thinking upon national rather than individualistic lines. Nor does it seem to us that within the electricity industry any great harm has been done; for, certainly, in meeting needs for a rapid extension of electricity supply and in welcoming the advent of nuclear power, the C.E.A. has been more successful in serving the nation than certain other similar bodies. Under the new proposals, supposing them to pass intact through Parliament, the ills traceable to centralisation will disappear. But there may well prove to be other ills to take their place, ills traceable to the lack of central authority. What, for example, will happen to rural electrification? Dependent upon individual boards' financial situations policy may diverge; for there is always an element of subsidy involved. Is it or is it not right that some rural areas should and some should not be favoured? Essentially, under the proposals, the present authoritarian regime is to give way to something more democratic in which each board bears ultimate responsibility not to an authority, but to the Minister for its own well-being. How far, we wonder, will the influence of the council be felt amongst the boards? Broadly, the boards are required to report their activities to the council; but the council will have little if any power to enforce its decisions on the boards except, presumably, by a somewhat distasteful appeal to the Minister. Clearly under such a system there seems little need for a large central staff. The council will presumably express approval or disapproval of proposals put before it in principle, not in detail. It appears to us, therefore, that unless, by amendment in Parliament, more powers are given to the council, great demands will be made upon the tact and diplomacy of the chairman and deputy-chairman to be appointed. They will need to make it demonstrably worth while to the Area Boards that the council should be consulted and that its advice and criticism should be appreciated. For unless the council earns the respect of the boards there could be, though we do not think there will be, chaos.

THE LOCOMOTIVE SUPERHEATER

The publication in our last two issues of Mr. Poultney's articles on Locomotives of 1906 reminds us that in 1906, fifty years ago, the Schmidt type flue tube superheater was first fitted to locomotives on British railways. The present year is, therefore, the jubilee year of the superheater, probably the greatest single advance made in the development of the steam locomotive since the introduction by Stephenson of the multitubular boiler when the engine "Northumbrian" was built in 1830. In fact, it is possibly not too much to say that, just in the same manner as the Stephenson boiler made the steam locomotive practicable for rail traction, so also has the perfecting of the high temperature superheater made modern high-powered locomotives possible.

The Engineer
100 Years Ago
(DECEMBER 5, 1856)

"CHRISTMAS IMPLEMENT SHOW"

"During the 9th, 10th, 11th and 12th of the ensuing week the Smithfield Club's annual exhibition of fat stock and implements in the Bazaar, King-street, Baker-street, takes place. In both departments, the number of exhibitors is unusually large, and the entries consequently more select and meritorious, promising a season of much gratification to all interested in the prosperity of British agriculture. In the implement department upstairs, there are 306 small rectangular areas, technically termed stands, divided among 119 exhibitors, and fifteen below for steam engines and threshing machines. Yesterday was the last day of entry for implements and machinery; this day and tomorrow the whole will be arranged for exhibition, each article being ticketed with its price. . . . . Next week we hope to be able to give a full report of implements and machinery. Meantime, we may draw our readers' attention to the non-architectural character of the Bazaar; the inadequate space allowed exhibitors in the implement department, and the exorbitant charges nevertheless paid. . . .

"A great metropolitan Hall of Industry is very much wanted for this annual exhibition, and many other purposes, such as public meetings. The truth of this proposition has often been acknowledged, and will appear manifest to every engineer or architect the moment he enters the Bazaar on any of the days of the show. . . . In the first place, let them glance at the high rank of the exhibitors, and all who take an interest in the show; next let them survey the anomalous and non-sanitary character of the place into which the metropolis annually jumbles our sovereign and nobility in a manner not very easily described, but which may be very easily seen next week in the Bazaar. The non-sanitary state of the cattle department deserves special notice. The carbonic acid gas given off from the lungs of fat stock, the sulphuretted hydrogen gas generated and pouring into it, are not exactly what the British capital ought to give her sovereign and nobility to breathe, to say nothing of those who are supposed to be inured to anything . . . ."

The credit for making the first application of a superheater to locomotives on our railways is due to Sir John Aspinall, who devised and fitted a form of smokebox superheater to some large passenger engines in 1899. This historic fact is the more interesting because, just as Sir John's superheaters were fitted to Lancashire and Yorkshire engines in 1899, so also, in 1906, was the Schmidt type fitted experimentally, which, together with the Great Western application, constituted this important locomotive development of fifty years ago. The Aspinall superheater, like others of the smokebox design and which included Schmidt's early applications, met only with partial success. Smokebox temperatures are not high enough, or at least should not be, to impart any large degree of heat to the steam. No doubt recognition of this fact led to Schmidt's further investigations, resulting, as is well known, in the idea of arranging the superheating piping in enlarged boiler tubes and to the ultimate development of the flue tube superheating equipment, which has entirely revolutionised the capacity and economy of modern steam locomotives. The Schmidt original conception, though a comparatively simple device, left much to be desired, and the apparatus since made available has been the work of many, including railway locomotive engineers and the manufacturers, who, as is well known, have greatly improved the component parts, perhaps more particularly the manufacture of the elements necessary for the reliability of the superheater.

From the working results obtained with the first applications, it quickly became apparent that large economies were realised and that with an increasing amount of superheat imported to the cylinder feed steam still larger gains would be attainable. Numerous experiments carried out indicated that fuel consumptions could be reduced by 20 per cent and even more. Sir William Stanier, in his presidential address to the Institution of Mechanical Engineers in 1941, gave the savings as 15 to 20 per cent obtainable by the application of "a relatively simple apparatus." Actually, tests have shown higher economies, which depend upon operating conditions. From the practical viewpoint of operation, a valuable result found with locomotives using highly superheated steam is the fact that fuel consumptions in relation to power developed show comparatively little variation over a large range of power output at defined constant speeds. Whereas engines using saturated steam show steeply rising fuel consumptions with increasing powers, those fitted with the superheater show much less variation in fuel rates, owing to the fact that increasing evaporations with increasing powers bring higher steam temperatures and specific volumes of the steam supplied to the cylinders, which, taken together, tend to stabilise the weight of steam supplied to the engines and the coal consumption in relation to the powers developed. The pioneer work undertaken half a century ago by George Hughes and G. J. Churchward, of the Lancashire and Yorkshire and Great Western Railways, when fitting the Schmidt flue tube superheater, will always be regarded as marking a milestone in the history of locomotive engineering.

A Seven Day Journal

Nuclear Energy Trade Associations' Conference

It has been announced that, in order to establish a permanent means of liaison on matters related to nuclear energy and associated developments, the Nuclear Energy Trade Associations' Conference (N.E.T.A.C.) has been formed. Membership of the Conference in no way restricts the autonomy of the participants, and is open to those trade associations which are concerned with nuclear energy equipment. The founder members are: the British Chemical Plant Manufacturers' Association, the British Electrical and Allied Manufacturers' Association, the British Engineers' Association, the Scientific Instrument Manufacturers' Association, and the Water-Tube Boilermakers' Association. It is stated that the decision to form N.E.T.A.C. was taken in the knowledge that British industry has made, and will continue to make, an increasingly important contribution to the development of the peaceful uses of nuclear energy, and that the number of manufacturers in the United Kingdom, concerned with one or more aspects of nuclear energy, is rapidly growing. N.E.T.A.C. says that it has already initiated action to make better known overseas the achievements of British industry in the nuclear engineering field. For the present, the chairman of N.E.T.A.C. is Mr. W. K. G. Allen, of W. H. Allen, Sons and Co., Ltd., who is the president of the British Engineers' Association. The address of N.E.T.A.C. is c/o The British Engineers' Association, 32, Victoria Street, London, S.W.1.

Proposed Site for Nuclear Power Station in Somerset

The Central Electricity Authority states that a site at Inkley Point in Somerset has been investigated to determine its suitability for a nuclear power station. The site is on the Bristol Channel coast of Somerset, about 4 miles west of the River Parrett. Surveys indicate (says the C.E.A.) that good foundation conditions, for carrying the heavy loads of the reactor and other plant, would be provided by the existence of limestone rock a few feet below the surface. Plentiful cooling water supplies are available. The proposed station at Inkley Point would be connected to the National Grid and could eventually supply the growing demands for electricity in the Bridgwater and Taunton areas, which have hitherto depended upon supplies from more distant power stations. Accordingly the Authority concludes that the site should be developed for the third C.E.A. nuclear power station (the first two being at Bradwell in Essex and Berkeley in Gloucestershire), subject to the approval of the Somerset County Council and the local planning authority and to the consent of the Minister of Fuel and Power.

Large Air Liners

Five Bristol "Britannia" 305 air liners are to be supplied next year to Northeast Airlines for use on services between New York and Florida. The "300" series aircraft, the first of which flew this July and is now in South Africa performing tropical trials for its Certificate of Airworthiness, are 142ft in span and are powered by four Bristol "Proteus" 755 engines. Their cruising speed of 400 m.p.h. will be unrivalled in the U.S.A., and they will reach Miami in three hours thirteen minutes. The aircraft for Northeast Airlines will accommodate either ninety-two passengers five abreast, or 133 six abreast, and can rapidly be altered from one to the other. The East Coast route is rich in traffic, but fluctuates through the year, being heaviest in the winter. Before Northeast Airlines were awarded this route only two carriers served it: other operators contend that there is traffic enough to justify a fourth participating. It is stated that the five "Britannia" air liners ordered by Northeast Airlines are in an advanced stage of construction at Short Bros. and Harland, Ltd., Belfast, where a second production line has been established. The first three are already structurally complete, and the fourth and fifth are nearing the final assembly stage.

Improvement Schemes for Newport and Barry Docks

The British Transport Commission is to install additional port facilities costing £1,365,000 at Newport and Barry Docks in South Wales. Most of the expenditure, namely, £1,100,000, will be at Newport, where transit sheds, quay cranes and other mechanical equipment and improved road and rail access are to be provided. The layout of South Quay, South Dock, is to be improved and a single-storey transit shed, 600ft long and 100ft wide, with two overhead gantry cranes, will be constructed. Twenty electric level luffing quay cranes, of 6 tons lifting capacity, with a working radius of 70ft and capable of dealing with the many cargo liners which regularly trade to the port, will be installed. At North Quay, North Dock, which is used by smaller classes of vessels, the hydraulic cranes will be replaced by electric cranes displaced from the South Quay. A single-storey transit shed, 220ft long and 75ft wide, will be constructed. At Barry docks a new berth, costing £265,000, is to be built for vessels laden with bulk dry cargoes, such as imported coal, scrap iron and steel, ores and chemicals. The new berth will be on the north side of No. 2 dock and will be 570ft long. It will be equipped with five electric quay cranes of 10 tons lifting capacity and a radius of 70ft.

Conference on Technical Illustration

On Thursday and Friday of last week, a conference on technical illustration was held at the L.C.C. Central School of Arts and Crafts, Southampton Row, London. Its object was to introduce to Principals of Colleges the recently launched syllabus for courses in technical illustration devised by the City and Guilds of London Institute, and it was accompanied by an exhibition of the works of technical illustrators to which a number of firms contributed examples. The conference was opened by an introductory talk by Mr. B. C. Lucia, deputy director of the Institute. There followed a talk on the "General Development of Technical Illustration" by Major H. R. Hockley, chairman of the Institute's advisory committee which devised the syllabus. On the following day, Principal W. J. L. Gaydon described in some detail how the syllabus had been put together and why it took its particular form and what was its particular purpose. A discussion which followed indicated that a number of the Principals present had under consideration the starting of courses in the subject of technical illustration. Full details including copies of specimen examination papers, can be obtained from the City and Guilds of London Institute, Gresham College, Basinghall Street, London, E.C.2.

550MW Generating Sets for C.E.A.

We learn that the Central Electricity Authority is planning to install, as part of its programme of power station construction for 1962, a turbo-generator of 550MW capacity, which is believed to be larger than any at present projected elsewhere. Because of the limitation on the maximum weight that can be transported by road the 550MW generating set will consist of a two-shaft cross-compound arrangement of two 275MW generators. A number of 275MW turbo-generator sets is also included in the 1962 programme, and they will consist of a single-shaft tandem-compound turbine arrangement. For both sizes of generating sets the initial steam conditions will be 2300 lb per square inch and 1050 deg. Fah. with one stage of reheat, conditions which are comparable with those for the 200MW sets already included in the programmes for 1959, 1960 and 1961. To stimulate further progress application of higher steam conditions, on a limited scale, is also being investigated.

Obituary

SIR AUSTIN HUDSON, BT.

We deeply regret the death of Sir Austin Hudson, Bt., which occurred in hospital in London, in the early hours of Thursday, November 29, after several weeks' illness. Sir Austin, who was fifty-nine, was Conservative Member of Parliament for Lewisham North, and was also the chairman of Morgan Brothers (Publishers), Ltd., proprietors of The Engineer.

Sir Austin Hudson, Bt.

Austin Uvedale Morgan Hudson was the son of the late Leopold Hudson, F.R.C.S., and the grandson of Septimus Vaughan Morgan, who, in 1859, was one of the founders of The Ironmonger and The Chemist and Druggist. Sir Austin was educated at Eton and Sandhurst, and in the first world war was commissioned in the Royal Berkshire Regiment, transferring subsequently to the Guards Machine Gun Regiment. He was placed on the reserve in 1920, in which year he became a director of

Morgan Brothers (Publishers), Ltd. Two years afterwards, Sir Austin began a distinguished political career by being elected to the House of Commons as Conservative member for East Islington. In the general election of 1924, Sir Austin was returned for North Hackney, a seat which he held continuously until 1945. During that twenty-one year period Sir Austin was appointed to various Government offices. From 1931 to 1935, he was a Government Whip and a Lord Commissioner of the Treasury, from 1935 to 1939, Parliamentary Secretary to the Ministry of Transport, and in 1939 he was appointed Civil Lord of the Admiralty. Upon relinquishing that office when the Government was reconstructed in 1942, Sir Austin was created a Baronet. He was then able to resume his directorship of Morgan Brothers (Publishers), Ltd., though a short break in it had to be made in 1945, when in the "caretaker" Government of that year he was appointed Parliamentary Secretary to the Ministry of Fuel and Power. In the 1950 election, Sir Austin went back again to the House of Commons as member for Lewisham North, a seat which he continued to hold until his death. In the last six years his parliamentary duties have included those of a temporary Chairman of the House and a Chairman of Standing Committees.

Although he was, for so many years, a keen and able House of Commons man, Sir Austin's interests were not restricted to the political sphere. He was greatly interested in all matters concerned with health, housing and the special problems of elderly people. He was honorary treasurer of the National Association for the Prevention of Tuberculosis and was a Governor of Westminster Hospital. In addition, Sir Austin at all times gave close attention to the affairs of the industries represented by this and the other technical and trade journals published by his company. In 1943, he was elected Senior Warden of the Worshipful Company of Ironmongers, and became Master of the Company in the following year. Sir Austin was appointed chairman of Morgan Brothers (Publishers), Ltd., in April last, having been vice-chairman of the company since April, 1948.

A memorial service for Sir Austin is to be held at 12 noon on Friday, December 14, at St. Martin-in-the-Fields, Trafalgar Square, London, W.C.2.

R. W. DANA, O.B.E.

NAVAL ARCHITECTS, particularly those of the older generation, will learn with regret of the death of Mr. Robert Washington Dana, which occurred at his home at Cockmoyle Rock, Cornwall, on Monday last. Mr. Dana, who was born in 1868, was the son of William Dana the marine painter, and received his education in Paris, then at Clifton College and later at Pembroke College, Cambridge. After leaving the university he became a civil engineering pupil with Sir John Wolfe-Barry. In 1901, Mr. Dana was appointed Secretary of the Institution of Naval Architects, a post which he continued to hold until his retirement in 1935, when he was made an honorary member. During his tenure of office he edited the "Transactions" of the Institution and was awarded a gold medal for his work for the Jubilee meeting of 1911. For his services during the 1914-18 war at the Ministry of Munitions, as assistant director of Artillery Supply for the Allies, he was awarded the Order of the Crown of Belgium.

Test for Detecting Real Changes in Frequency

By STAFFORD BEER*

Suppose something can happen in one of two ways, like tossing a coin. Sometimes we have to judge whether the frequency with which one of these ways is happening (as opposed to the other) has a special meaning or whether it can safely be attributed to chance. For instance, suppose we obtain sixty heads and forty tails from a hundred tosses: shall we say that the result is haphazard or that the coin is biassed? The simple test described in the article is designed to take the guesswork out of that sort of problem. It will say whether the suspected frequency is safely described as a chance result or not. By "safely" is meant that the theory on which the test is based is worked out so that the answer it gives will be right ninety-five times out of one hundred. It is impossible to fix conditions so that the answer is certainly right.

COMPARING AN ACTUAL RESULT WITH A "BUILT-IN" EXPECTATION

PRODUCTION has run into trouble: in the course of this week there have been seventy-eight stoppages to machines of a certain type. Equal quantities of product A and B have been made to a mixed programme. The manager finds that forty-six of the stoppages concerned product A, and thirty-two concerned product B. Should he conclude, in the absence of any other fact, that A is more prone to this sort of trouble?

If the products are equally prone, then there is a built-in expectation that the two products are each concerned in thirty-nine incidents. In fact, A is concerned in forty-six and B in thirty-two. Choose the result which is *lower* than the expectation—in this case B. Apply the actual result (thirty-two) to the right-hand axis of the attached chart and the total number involved (seventy-eight) to the horizontal axis. These are the two co-ordinates of a point on the chart which can be marked. (Note that the co-ordinates are to be drawn at right angles to the axis; the curves on the chart are quite independent of the scale calibrations.) Now find the curve for the expected value (thirty-nine)—the scale is marked on the diagonal with ringed numbers. Is the point we found above or below this curve? It is above. Therefore the evidence is not good enough to convince us that product A is more prone. The outcome is likely to be a chance fluctuation; tomorrow there may be more stoppages on product B.

Consider the same problem with different figures. Suppose that product A was involved in fifty of the incidents and product B in only twenty-eight. Again the built-in expectation is thirty-nine (so we use the same curve as before), and the total number is still seventy-eight (so we use the same point on the bottom axis). This time, however, we enter twenty-eight on the right-hand scale. The point on the chart is now *below* the curve. We now have very strong evidence to suggest that the trouble *is* associated with product A more strongly than with B. Our remedial action should therefore be concentrated on A first.

Let us now make the circumstances a little less straightforward. There are still seventy-eight incidents, spread over products A and B. The products have been made to a mixed programme, as before, but two-thirds of the output have been A's and only a third B's. This time forty incidents concern A and thirty-eight concern B. There is still a built-in expectation, but it is not now thirty-nine on each product. Since two-thirds of the output is of A's, then (if A and B are equally concerned) there should be fifty-two incidents involving A and twenty-six involving B. Again we take the result which is lower than expectation: this time it is for product A. We find the point given by a total of seventy-eight (as before) and an "actual" on the right-hand scale of forty. This point is *below* the expectation curve of fifty-two, and hence we may accept the difference in frequency as a real difference. Product B is especially prone to the trouble.

If the actual result had given forty-five A's and thirty-three B's, we should have conceded that the outcome might easily be due to chance (this may be tested on the chart). It is probably clear by now that it is not at all easy to make this judgment intuitively. And yet, how important the judgment could be. A manager cannot afford to send his people away to look for the characteristic which makes one product more susceptible to trouble than another, if the "difference" is illusory. Expensive plant time can be wasted while they are on this wild goose chase.

COMPARING AN ACTUAL RESULT WITH OTHER EXPERIENCE

A manager has been buying a certain tool for years, and is now pressed by the manufacturer of a rival tool to change his supplier. He decides to hold a test of the two tools, in identical conditions, and has twenty items made with each one. These items are subjected to the most rigorous inspection. There is no built-in expectation of the number of rejections. The technique here is to run the test on the tool in use first and to use the result as the "expectation" of the result to be obtained by the challenger.

This, let us say, is the result—a complete reversal:—

	Perfect items	Items with flaws
Tool in use	8	12
Challenging tool	12	8

The manager is perhaps tempted to think that the rival has made his case; but he decides to test the outcome. The result which is *lower* must be used; so he tests an "actual" of eight, over twenty incidents, against an "expectation" of twelve. The result is probably due to chance. So the test does *not* show the new tool to be better. What does it show? Certainly not that the new tool is worse! The conclusion is that there is not enough evidence to decide. The manager, who thought that twenty trials would suffice must now hold more.

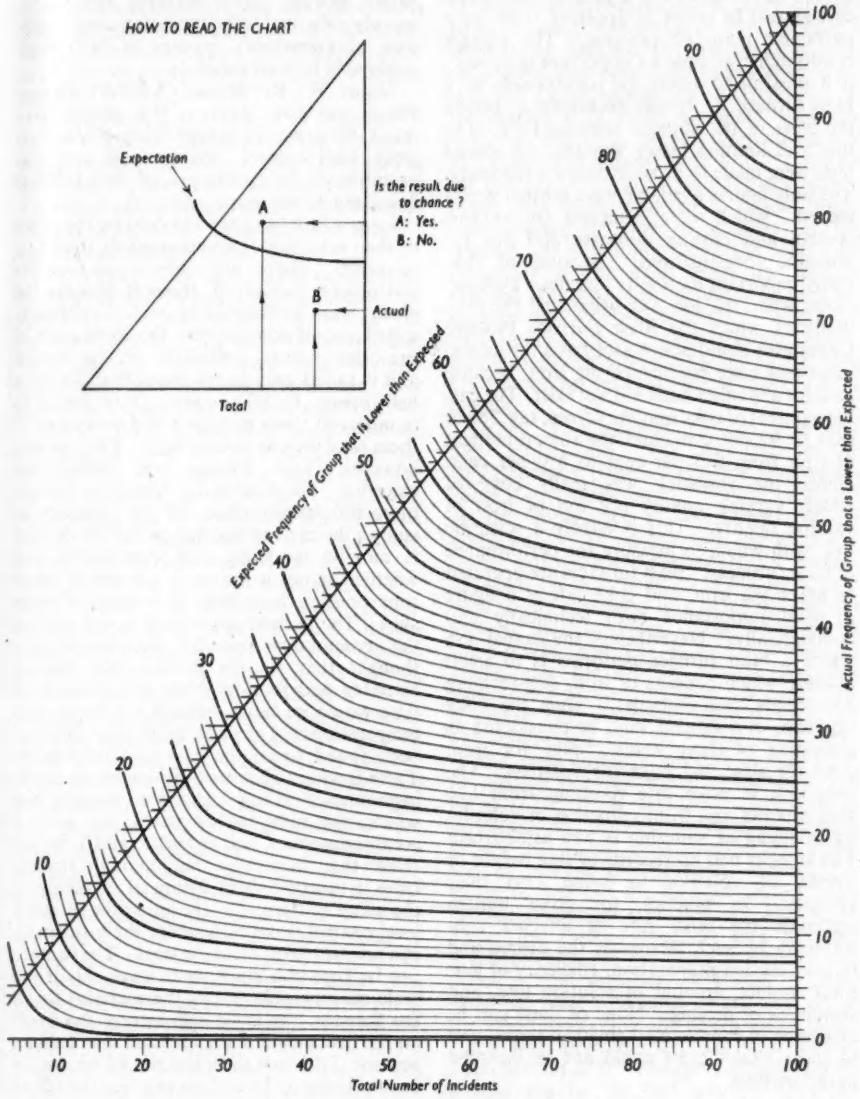
Suppose that he holds a further twenty trials, bringing his total sample to forty. The result is maintained; the table reads:—

	Perfect	Flawed
Tool in use	16	24
Challenging tool	24	16

He now tests this (actual sixteen, total forty,

* Samuel Fox and Co., Ltd.

expectation twenty-four), and he finds the point is "below the line"; the change is *real*. Since the improvement has been no more than maintained, he may feel surprised that the "chance" conclusion has now become a "significant" one. But the very fact that the new tool has kept up its performance is what has turned the scale. Obviously the repetition of events plays a big part in their evaluation, and statistics recognises this. (If of all the people I passed to-day one was the Prime Minister, I should note the occasion as remarkable. But if I met him to-morrow as well, and the next day, and the next, I should begin to think he was following me about.)



Expectation Chart

Beware of Percentages

The previous example demonstrates how dangerous ratios can be. Quite the most dangerous is the percentage, because it is so familiar and convenient. It is very easy to test this statement, and easy to see the reason for it.

Suppose that of fifty items costed, thirty-one are better than average. The manager would like to think this means his efficiency is improving—because the built-in expectation is that only twenty-five will be better than average (in normal conditions). What he should do is to test this result, twenty-five, against an actual nineteen (the falling frequency) over fifty items. He will then have to discuss this result as probably a chance variation, and to keep up his attention to cost. If, however, he allows himself to say: "I am better than average on 62 per cent," he will test fifty against a (so-called) actual thirty-eight, over 100 items, and will conclude that his efficiency *has* improved.

To do this is simply to pretend to yourself that you have got better results than you have. Never use a percentage in this test. It "manufactures" information—which may or may not be spurious. It supposes that the next fifty results will also give thirty-one items better than average, and that, of course, remains to be seen. If, to-morrow this is the result, the manager can test his sixty-two items legitimately: he will conclude, rightly, that his results have improved. In the meantime, he has no business to assume to-morrow's figures; and in this context that is what a percentage means.

Two Footnotes

You may think that the precise, thin line drawn on the chart—although it has statistical justification—is a trifle arbitrary. And so it is. Returning to our first question: Is a coin biassed if it yields sixty heads and forty tails from 100 throws? The falling frequency is forty tails against an expectation of fifty, over 100 items. The point on the chart is a fraction above the line, and the coin is not biassed. But if there had been sixty-one heads to thirty-nine tails, we should have said the coin *is* biassed. In fact, the theory is worked out for an exactly 5 per cent chance of being wrong. It is that figure which is arbitrary. Why should we not run a fractionally greater risk, and call the sixty/forty result biassed? It is up to the manager. On the whole, he would be well advised to interpret results which are very close to the line in the least favourable way. The general rule is: increase the number of trials until you get a firm result.

I should be the first to agree that very often there are more reliable statistical tests than this which could be applied to yield more information. If this acknowledgement leads a manager to say he will employ a statistician, so much the better. But if not, I suggest that it is better that the manager should make use of this easily handled technique than that he should just guess.

Theoretical Basis

This test is based on a transformation of the chi-square statistic, as it applies to the special case of the dichotomous classification of frequencies. In its general form, the test compares observed with expected frequencies over k exhaustive and discrete categories according to the statistic:

$$\chi^2=\sum_{i=1}^{k}\left(\frac{(O_i-E_i)}{E_i}\right).$$

In this application, the general case is constrained by: (*a*) the integral value of frequencies, (*b*) $k=2$. Yate's correction must therefore be made for discontinuity of the variable.

Let:

the Expected values $=a, b(>5)$
the Observed value$>a$, $-0{\cdot}5=\alpha$ $(>5{\cdot}5)$
the Observed value$<b$, $+0{\cdot}5=\beta$ $(>5{\cdot}5)$

so that: $a+b=\alpha+\beta=n$
and: $\alpha-a=b-\beta.$

Then:

$$\chi^2=(\alpha-a)^2/a+(b-\beta)^2/b.$$

Transforming this we obtain a quadratic:

$$\beta^2-2b\beta+b^2-\chi^2ab/n=0$$

the root (since $\beta<b$) being:

$$\beta=b-\sqrt{\chi^2b-b^2(\chi^2/n)}.$$

Hence the observed value which is lower than expectation is derived:

$$\phi=b-\sqrt{\chi^2b-b^2(\chi^2/n)}-0{\cdot}5(>5).$$

The chart is based on the value for χ^2 such that the probability $P=0{\cdot}05$, with one degree of freedom. It plots the family of *b*-curves for all integral "expected" values 5–100, on the discontinuous base n, against the observed value ϕ (which is treated as a continuous variable for graphical purposes, although interpolation between integral values is actually invalid).

Acknowledgments

Acknowledgment is due to the management of S. Fox and Co., Ltd., for permission to publish, to Mrs. A. Mutch, who carried through the computation required to specify the curves, and to Mr. C. D. Morris who drew the chart.

Iron and Steel Institute

AUTUMN MEETING

No. II—(*Concluded from page 766, November 30*)

DURING the autumn meeting of the Iron and Steel Institute, in London, the following papers were discussed jointly at the afternoon session on Wednesday, November 21.

AUTOMATIC STOCK LEVEL CONTROL ON BLAST FURNACES

By I. KJELLMAN and K. GRONBLAD

SYNOPSIS

The need for better stock level control is briefly discussed. An account is given of a successful measuring device, suggested by various authors and adopted by Oy Vuoksenniska Ab, Finland. Some details are given of a new automatic stock level controller and of the favourable results obtained.

THE MEASUREMENT OF GAS TRANSIT TIMES IN A BLAST FURNACE

By T. W. JOHNSON

SYNOPSIS

A method of determining quickly the transit time of the blast from a tuyere to various points along the stockline or of making a number of successive measurements at one point is described. A variation of this method to permit continuous sampling at two points simultaneously is outlined. Some experimental results are given proving that the technique is straightforward and satisfactory on a driving blast furnace.

STUDIES OF BLAST FURNACE ASSESSMENT

By J. M. RIDGION and A. M. WHITEHOUSE

SYNOPSIS

For several years attempts have been made to establish the correlation between the many factors that control blast furnace performance. Statistical techniques, such as multiple regression analysis, which involve the study of a large number of values relating to each factor, have been applied.

In order to condense the time required for the mathematical work, use was made of the Ferranti computer installed at Manchester University, and details are given of the results obtained from a study of seven furnaces.

DISCUSSION

Mr. T. H. Hodson (Kettering Iron and Steel Company): The work of Mr. Ridgion and Mr. Whitehouse was originated in the hope that a method would be developed which would enable the performance of furnaces to be compared, although they might be smelting different kinds of ores and producing different kinds of iron. Unfortunately, the net result of the authors' efforts is represented by the six coefficients—for total burden; lime/silica ratio; blast temperature; percentage of hard ore; percentage of sinter; and iron silicon—which are put forward in their paper. These appear to be a poor harvest after the prodigious labour involved, particularly as no progress appears to have been made towards the goal of relative assessment of different furnaces. It is necessary to remember that pig iron has been made in blast furnaces in this country, and abroad, for over two centuries. The fact that a basis for furnace assessment has not been established in all those years is surely an indication that the problem is an unusually difficult one. I therefore prefer to regard the work done so far as one stage of preliminary exploration of the problems of assessment.

The six coefficients have been derived from Table II (of the paper). Examination of this shows that the coefficient for total burden varies from 0·084 for Redcar No. 4 to 0·277 for Bessemer No. 5. The proposed coefficient is 0·15; hence it needs reducing by 44 per cent to suit Redcar No. 4 and increasing by 85 per cent for Bessemer No. 5. Similarly, the coefficient of 0·4 cwt reduction of carbon for 100 deg. Cent. increase of blast temperature needs reducing by 67 per cent for Sheepbridge and increasing by 25 per cent for Bessemer No. 5. Other variables show similar inconsistency. Obviously the coefficients can be regarded as being only of a general nature and care should be taken in applying them to a particular plant or practice. The meagre results achieved pose an important question; is it possible to assess the performance of a blast furnace? It may be helpful to review the basis of the authors' investigations. The first and limiting factor was that no special tests were made to provide data for the study. The only figures available were normal works records, which were compiled for routine control and costing purposes and not for scientific investigations. Because of this, many important data were missing. Furthermore, when the job was originated the only yardstick which the Blast Furnace Practice Committee could adopt as a basis for assessment was coke per ton of pig iron, because data for any other basis did not exist. The carbon content of coke may vary from, say, 78 per cent to 92 per cent, and the silicon content of iron from 0·3 per cent to 5·0 per cent. Hence the yardstick was really coke of widely varying quality per ton of iron of varying quality. This is hardly a scientific unit with which to measure the performance of blast furnaces. Blast furnaces are operated to make pig iron, and coke rate is a figure of vital importance both technically and commercially. Nevertheless the actual job which a blast furnace performs is to smelt burden, which consists of iron, slag-forming contituents, and volatiles. Thus the coke rate can, in a general way, be considered as consisting of three items: coke for iron, coke for slag, and coke for volatiles. The reduction in coke rate resulting from low slag volumes and from reduction of volatiles by calcining or sintering is well established. The authors had no records of slag weight or weight of volatiles to bring into their analyses. In practice, for given burden materials the coke rate is affected substantially by such factors as the degree and type of burden preparation, efficiency of gas/solid contact, amount of solution loss, and steadiness of driving. None of these can be expressed in concise mathematical terms, and so these vital factors could not be included in the analysis.

I realise that the authors' work consisted of statistical analysis of the available data, but the data were totally inadequate. There will probably be general agreement that the authors did not have a chance to achieve their goal of relative furnace assessment, and so the question remains unanswered. Nevertheless, we are faced with the position that the blast furnaces of Britain consume over 12,000,000 tons of scarce and expensive coke per year, and we do not know how efficiently, or how inefficiently, it is being consumed. I suggest, therefore, that the difficulties revealed by the present paper should be accepted as a spur and stimulant for a fresh attack on the problem. There are so many interrelated factors which affect the performance of a blast furnace—the authors used thirty and did not have half the picture—that I cannot foresee the complete picture ever being available on a commercial blast furnace. The chances of it being available for a number of furnaces are even more remote. This makes me believe that an entirely new approach to blast furnace assessment is called for. In this connection I suggest that we might find inspiration from the work of the steam engineers. In 1778 they defined the performance of their Cornish pumping engines in terms of the number of pounds of water raised 1ft high per bushel of Swansea or Durham coal. The evaluation of the mechanical and electrical equivalents of heat enabled them to adopt a world-wide standard method of assessing the performance of prime movers, power stations and so on, namely, thermal efficiency per cent. This unit of assessment appears to be equally applicable to blast furnaces.

Major W. R. Brown (Ashmore Benson Pease and Co., Ltd.): We should very much welcome the paper from Finland on stock level control, because it is a typical example of the machinery of this Institute being put to its proper purpose.

I am a little surprised to read in the paper of their selection of an intermittent stock line recorder. There are two forms of this instrument: In one of these it plumbs the stock level intermittently and is normally raised out of contact with the stock, and in the other it rests continually on the burden and is raised only at the times that the large bell opens. In this country there are large numbers of these recorders and every one of them is of the continuous type. The authors, however, have chosen an intermittent recorder. The continuous type gives a much more informative chart for the operator to study; he can see whether or not the burden is moving gradually and consistently and whether or not it moves in a series of small slips or sometimes even in a series of large slips. The authors say that they did not use the continuous recorder because it was thought that, as the furnace was making hematite and foundry iron, the intermittent type would be more suitable for higher top temperatures. I do not think that that has been found to be the case in this country. There is within 12 miles of where we are meeting a furnace making high silicon foundry iron which, for over twenty years, has used a continuous stock line recorder, and I do not think that they have had enough trouble from it to make them dream of changing to the other pattern. On the question of stock level control, I doubt whether the instrument can do much to control the level. The furnace can be kept at a given stock level only if the scale car operator brings the material to fill the furnace. It is no use setting the knob on the instrument if the material is not there, because if it is not there the stock line cannot be maintained. In normal practice the filling equipment is ample to ensure that material is always at hand ready to go into the furnace, so that it is quite easy to maintain the standing order that when the stock level is at a certain point, usually 2ft to 3ft below the open bell, the furnace is ready to receive another charge, and the next charge is dumped. The question seems to arise of whether the dumping should be done automatically or whether it should be left for the scale car operator to initiate the dumping, which on the modern furnace is done merely by sending up the next skip of the next round. The bell is charged and ready to dump, and it dumps automatically as soon as the man sends up the next charge. He can send up the next charge only when the furnace has room to receive it.

Mr. A. Stirling (Stewarts and Lloyds, Ltd.): I believe that Table I of the paper by Ridgion and Whitehouse would be improved if the size of the furnace was

included—the hearth diameter and the useful working volume. I believe that the age of the furnace in its campaign should also be shown. The authors might also like, as a matter of convenience, to show the coke-burning capacity on some unit basis, the Rice or some other. In my own experience of assessment studies, which, of course, does not go anything like so far as that of the authors, I have always found it first of all a good plan to set out the data in the form of an Fe balance. It shows where the silica and the lime are, and it is a reasonable check on a sulphur balance. Do the authors think that they are likely to get a Fe balance within 3 per cent and that that is a reasonable basis on which to begin a more complex study ?

Taking Tables II, III and IV together, I think it will be agreed that the Bessemer No. 5 furnace stands out on its own and is on a much higher level than all the others. The others might be regarded as one, because they are almost the same—the two Redcars and the two Sheepbridges.

Mr. Ridgion referred to the French thought on this matter, which I think is also the American line of thought, of taking the variables in descending order of importance. That might be useful if only we knew their descending order of importance or their ascending order. We do not know all the variables. It is true that there is a formidable list, and we have any amount of information on silica/lime ratios on all the ores and on particular sizes down to −100 mesh, but perhaps it is the alumina/silica ratio that the operator would prefer the statistician to use, and we have not got that.

Mr. H. G. Jones (Steel Company of Wales, Ltd.) : I want to underline some of the difficulties of this work of blast furnace assessment, which are, of course, well known to the authors of the paper on this subject. It is no use simply putting all these things into the wash and hoping that the arithmetic will sort them out, as I think we shall all agree. The first and most obvious point is that the causes must be primary causes and not secondary causes. An example of that was provided this morning which is very apposite. In examining the influence of scarfing on quality the result was found, purely from analysis of the figures, that the more the scarfing that was done the worse the result. The reason we found that, of course, was that we were not looking at the primary cause. The primary cause was defects on the original slabs, which required more scarfing. The worst slabs received the most scarfing and still gave the worst result. I cannot help feeling that in some of this blast furnace assessment work we may have similar effects acting, and that we have not got down to the fundamentals of it. On rather a technical point, trend removal is essential but can give the wrong results. If the results are curvilinear, as most of them are, I feel certain that if the results are grouped around one end in the main this method of trend removal can be shown to give the wrong answers. It is a little dangerous to apply trend removal until we have some more information on how the variation takes place.

Dr. J. H. Chesters (United Steel Companies, Ltd.) : I should like to congratulate Mr. Ridgion and his colleagues on an excellent piece of work and one which must have called for a great deal of courage. The results obtained seem to be very much in line with the sort of experience which we in the United Steel Companies have had in recent years on controlled changes. We have found the amazing effect on coke rate of increases in the amount of sinter used. This is proof of the importance of work of this kind, because if ten years ago we had thought that changing from 0 to 100 per cent sinter would give us anything like a coke saving of 7 cwt per ton we should have been keener to do it. We found that out by trial and error, and it is only now that we are being told that we ought to have known.

Dr. D. W. Gillings (I.C.I., Ltd.) : Although I have been statistically not significant in the iron and steel industry for some time, there are two comments which I should like to make from experience in other process fields. I was interested in Mr. Hodson's comparison between the furnace and such well-established operations as power production and steam raising and his reference to the efficiency of these processes, which is based on well characterised thermodynamics and concerned entirely with heat. I am all for encouraging that in blast furnace assessment, but there may be a certain over-simplification in what he suggests for the furnace. If you simply took the total heat remaining in the gases from the furnace top, this could be affected simply by changes of coke reactivity which might or might not have an effect on the processes of iron reduction in the stack ; it might simply arise from the reaction between the fuel and the CO-CO_2 mixture.

Dr. T. P. Colclough (British Iron and Steel Federation) : My approach to the very important paper by Ridgion and Whitehouse is extremely mixed. We are all agreed on the importance of the subject, and I think we are all agreed that the time and money expended, and particularly the services of two of the best members of our staff, have been wisely expended in making an attempt to solve these problems. One is still left in some doubt, however, as to the method of attack and the validity of the so-called conclusions which have been reached. One is aware that statistical method takes all and sundry data that are available and seeks to find some common measure of agreement or relation between them. That may well be so ; but I am wondering—and I have expressed my opinion previously—whether or not that is the most suitable and useful way of tackling this problem. Frankly, in trying to find out the basis of correct blast furnace procedure I do not care two hoots about the rotten procedure and the bad practice which are prevalent in our old and obsolete blast furnaces. If I wish to make progress, what I do is to go up and down the world to examine the best practice which I can find anywhere and see what lessons I can get out of it. I suggest, therefore, that it may not be the best way of using the valuable time of our skilled staff to let them spend their time in examining a variety of practices and trying to correlate them. I would recommend that from now onwards, at any rate, having played about with this new toy and having found a way of using it, we should concentrate our efforts on trying to get the best results out of the best operating data that are available.

Secondly, I believe that the basis of this assessment is fundamentally unsound. The fundamental basis of the assessment is the weight of the burden going in. We all know by now that that is not the most important factor, and cannot be. If we have certain of our ores going into the blast furnace which contain 30 per cent volatiles, and the amount of heat required to deal with 30 per cent of volatiles is insignificant in comparison with the amount of heat required to smelt solid materials, then that 30 per cent cannot have the same assessment values anyhow. I suggest that, after all, the blast furnace is a heat machine, and therefore the only correct basis of assessment and computation must be the heat requirement and the utilisation of the incipient fuel that is put into the blast furnace. I differ, therefore, from the very start of this business with the method adopted. I must acknowledge that the authors have proceeded for some distance in the direction that I am indicating, because in the early days they spread their investigations over a wide range of blast furnace practice and came to the conclusion that the correlations which they found were not of particular value, and so in the present paper the examination has been confined to some half-dozen furnaces and they are getting very much better correlation. That is extremely surprising, because the best correlation that we get in this paper is given in blast furnaces where we know that the conditions of operation are under stringent control, as compared with others which did not show the same correlation and where the control is much less efficient.

Mr. A. M. Whitehouse (in reply) : Several speakers have criticised our approach and have said that we should have taken more account of the heat transfer and so on, and several have criticised our variables and said that they are very inaccurate. We have had to work with the variables we have. Because they are not accurate, or because they are not all-inclusive and because some are not recorded, it does not mean that the whole of the work is invalidated. In a complicated system such as this it is usually the case that the variables are extremely inaccurate and that not all that are wanted are available. We have got all that we could get, and that is our only excuse. As for a different approach, taking more account of the theory of blast furnace practice, we should welcome that. If people can give us other variables, derived from sound blast furnace theory, to put into other regressions we shall put them in with pleasure.

The second day of the meeting, Thursday, November 22, was devoted to the discussion of two series of papers, coming, as one speaker said, within " the general framework of physical metallurgy." In the morning, the following group of papers was presented :

" The Enthalpy and Specific Heat of Iron and Steel : A Critical Survey of the Methods of Determination," by J. R. Pattison ; " An Analysis of the Available Data on the Total Heat of Commercial Steels," by J. R. Pattison ; " The Enthalpy of a 0·12 per cent Carbon Steel," by J. R. Pattison and T. H. Lonsdale ; " The Enthalpy of Pure Iron," by J. R. Pattison and P. W. Willows, and " The Study of 7 per cent and 8 per cent Chromium Creep-Resisting Steels for Use in Steam Power Plant," by M. G. Gemmill, H. Hughes, J. D. Murray, F. B. Pickering, and K. W. Andrews.

The papers discussed at the concluding session were : " The Tempering and Nitriding of Some 3 per cent Chromium Steels," by C. C. Hodgson and H. G. Baron ; " Some Experiments on the Composition of Carbides in Low-Alloy Steels," by J. R. Bowers ; " Bainitic Retained Austenite," by J. A. Cameron ; " The Temperature of Formation of Martensite and Bainite in Low-Alloy Steels : Some Effects of Chemical Composition," by W. Steven and A. G. Haynes ; " The Tempering of Plain Carbon Steels," by E. D. Hyam and J. Nutting, and " An Electron Microscopic Examination of the Alloy Carbides Precipitated During the Fourth Stage of Tempering," by K. Kuo.

Calder Hall Reactors

No. II—(*Concluded from page 774, November 30*)

A symposium on Calder Works Nuclear Power Plant was held by the British Nuclear Energy Conference in London on November 22 and 23. Some aspects of reactor design and construction are given in the following abstracts from the paper on "The Design and Construction of the Plant," by R. V. Moore.

Reactor Core

Graphite Supply.—The heart of the reactor is the graphite core within which the uranium is distributed and which slows down the neutrons to thermal energies. Natural graphite occurs in fair abundance throughout the world, but contains many impurities. For the past fifty years, graphite has been manufactured from crude oil and coal-tar pitch, the product being used principally in the metallurgical industries. Graphite for use in reactors is required to be exceptionally free from neutron-absorbing substances and to be of high density. Improvements have been continuous over the last few years, reduced neutron cross-section stemming from the use of purer raw materials and the exceptional precautions taken in the cleanliness of the manufacturing process. In the Calder reactors, two qualities of graphite are used: the highest quality in the core, the remainder in the reflector surrounding it. About 2000 tons of rough bricks were required, from which 1200 tons of machined graphite components were produced, sufficient to build one structure. Samples from about 2 per cent of these bricks were taken to Harwell at regular intervals for the neutron cross-section to be checked by measurement in GLEEP, the smaller of the two graphite piles at Harwell, which has facilities for carrying out these measurements.

The graphite was machined from blocks approximately 8¼in square and 32in long in a workshop at the U.K.A.E.A.'s factory at Windscale. Some 60,000 components required machining, many being identical or similar in form. Jigs and fixtures were designed to permit flow-line production. Milling machines were extensively used because with this type of machine large amounts of material can be removed with a small cutting edge, which avoids chipping. A considerable technique in graphite machining has developed aimed at conserving graphite and reducing tool wear. Cleanliness in the machining process is essential; each cutting tool is provided with a hood connected to a dust extraction system, and all operators change into clean clothing before being admitted to the shop.

In the machine shop line, inspection positions were arranged after each finished machining operation, to avoid further machining of faulty components. This saved material as the rejected component could often be reclaimed for subsequent conversion to another type of brick.

After final inspection, each brick was placed in a stiff cardboard carton, closed and sealed by adhesive tape. The boxes of graphite were stacked by types in a store maintained at a high standard of cleanliness and reserved solely for the storage of graphite. To facilitate assembly in the reactor, each layer of graphite was separately detailed. From these drawings, schedules were produced which enabled the deliveries from the main graphite store to the limited buffer store at the reactor, to be made in the correct order of assembly.

The Graphite Structure.—The graphite structure is a twenty-four-sided regular prism 36ft across corners and 27ft high, weighing 1146 tons. It has 1696 vertical channels to accommodate the fuel elements and through which the CO_2 coolant passes: 112 vertical holes of smaller diameter are located at the centre of each group of sixteen channels. These are included primarily for the control rods and neutron flux plotting equipment.

Briefly, the main problem is to produce a structure which remains stable in spite of irradiation, temperature and pressure effects. In particular, any distortion which does take place during the life of the plant must not interfere with the uranium-charging functions or the operation of the control rods. In addition, leakage of coolant from the channels must be avoided. In all, the design problem is not an easy one.

Irradiation damage produces two effects. First, variation of the fast neutron flux causes stress concentrations in individual bricks; and secondly, graphite grows in size when irradiated, the rate of growth being dependent on its operating temperature and method of manufacture. However, a design solution was found which, it is expected, will ensure a long life (greater than twenty years) for the structure.

In order that forces are not applied unnecessarily to the main reactor vessel, connections between the graphite structure and the vessel are avoided, except for the support of its weight on the grid structure. This necessitates fitting restraining members around the perimeter of the structure at different levels which have no attachment to the vessel, but apply hoop restraint. If a simple solid band were used the expected dimensional changes due to graphite growth and differential thermal expansion would produce failure in the band. The restraining members therefore take the form of multi-tubular ties connected end to end, which will absorb the strain but still act as a continuous garter around the graphite structure.

The support of the graphite involved a number of special problems. As the coefficient of thermal expansion of graphite is smaller than steel, if the graphite columns were supported directly on a steel base plate, they would tend to separate as the temperature of the system increased. Alignment of the graphite structure with charging holes in the pressure vessel roof might also be disturbed. Rather than attempt to restrain the graphite to slide on the base plates, it was decided to use a form of rolling friction between the two materials. A ball bearing system having 18¼in diameter balls has been introduced under each column of graphite, capable of carrying a load of 12 tons under operating conditions (Fig. 8). The actual load carried is about ½ ton, giving an adequate safeguard against overloading. The balls and races are made of stainless steel with a hardness in excess of 47 Rockwell C scale, so that they will maintain adequate hardness under Wigner-release temperature conditions. The bottom races of the bearings rest on 4in thick steel plates which are supported by the grid structure. The plates have holes bored in them to allow entry of the coolant gas to the channels in the graphite.

As the bursting loads are greatly reduced by the substitution of rolling for sliding friction the restraint at the bottom of the graphite is subject to reasonably small loads. A number of simple brackets, associated with the bottom system of garter restraints, function as keyways engaging with keys welded to the outer edge of the support grid structure. This system of radial keyways permits relative expansion between the graphite structure and the support plates, while maintaining it in correct position relative to the charge holes in the vessel roof.

The vessel has an inside diameter of 37ft, leaving an annular gap between it and the graphite structure varying in width from 6in to 8in. As this gap communicates with both top and bottom headers, if left unsealed a formidable amount of the coolant would by-pass the reactor channels. After consideration of several possibilities, it was decided to seal at the bottom of the graphite stack where the vertical freedom required is limited to about 0·030in and the radial freedom to 1in. The seal is in the form of two horizontal metal diaphragms 0·2in thick, rigidly attached to a flange, welded to the vessel, and sliding in peripheral slots in the graphite structure. A double seal serves both to reduce leakage and to provide an insurance against the unlikely failure of either. The diaphragms are hard chromium plated to prevent corrosion, and have bearing strips attached to avoid wear between them and the graphite and to allow them to bend freely. Holes of ¼in diameter have been drilled in the gas seal to provide ½ per cent leakage flow between the graphite and the pressure vessel to cool the latter.

On the top surface of the graphite structure heavy castings referred to as "charge pans" are placed, there being one charge pan associated with each group of sixteen channels. These castings act as a ballast to hold down the top bricks and also form a point of support for the bottom spigot of the uranium charging chute and a robust funnel at the top of the cooling channels, which protects the graphite from damage. The proportions of the funnel section are such as to minimise pressure loss in the coolant. The charging pans have a secondary function in providing terminal points for the pipes which extract coolant samples for the gas sampling plant.

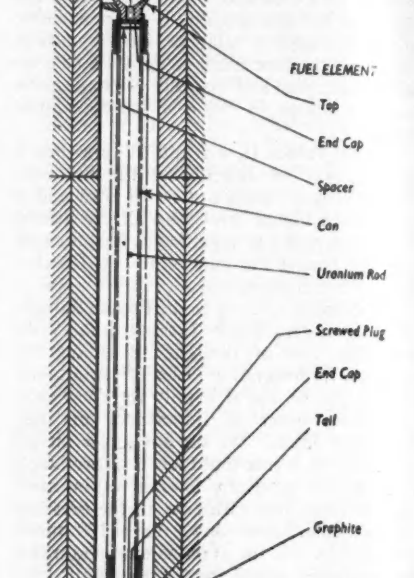


Fig. 8—Graphite and fuel element support

The Fuel Elements and Their Support.—In the skilful design and development of suitable fuel elements to be produced in large numbers, is invested to a very great extent the ultimate success of a reactor. A correspondingly large effort, not described in this brief account, was devoted to this problem. The support of the fuel

elements is, however, described in some detail, as it is a most vital matter of design. The fuel elements are solid rods of natural uranium, 40in long and of 1·15in diameter, encased in a magnesium alloy can which separates the uranium from the coolant and provides extended surfaces for heat transfer. There are six fuel elements in each channel, the complete reactor charge weighing 130 tonnes.

In the design study it was proposed to support the fuel elements individually in the vertical channels. On review, however, it was felt that the ledges in the graphite upon which each fuel element rested might tend, in the course of time, to break up under irradiation. Instead, it was decided to exploit the fact that the low-temperature end of the reactor is at the bottom and stack one fuel element on top of another, the maximum support load being associated with the coolest fuel elements, so that the effects of thermal creep were minimised. The load of the complete stack, about 170 lb, is transferred by a strut through a support boss which rests on the same plate as the bottom layer of graphite bricks, thus avoiding passing the fuel element load through the graphite itself. This plate forms the upper race of the thrust bearing, transferring the load of uranium and graphite to the 4in thick support plates which rest on the grid structure, in a manner already described. Fig. 8 illustrates the arrangement.

The support strut, itself an important member, is charged and discharged from the reactor in a similar way to the fuel elements. Being in the core, it must be fabricated of materials of low neutron cross-section, and yet withstand, without serious damage to either itself, the graphite, fuel element or the support boss the impact of a fuel element inadvertently dropped from the top face of the reactor. The top end is made similar to a fuel element top, and the strut itself is a graphite column enclosed in a magnesium alloy can, incorporating a sheer pin and broach at the lower end. It is located vertically and radially at its lower end by the support boss, and radially at the top by three arms. If a load occurs considerably in excess of normal the pin fails in double shear and the broach operates inside the tube, absorbing the energy of impact. If this occurs the whole strut assembly is withdrawn and replaced by a new one.

To control the coolant flow in relation to heat release it is necessary to introduce a restriction of the correct size into each channel. Consideration was given to placing the restriction either at the top of the fuel element stack or at the bottom. The former was rejected because of the difficulty of preventing it blowing out, and finally it was decided to fit a disc to the support strut forming a restriction between the disc itself and a defined diameter on an extension of the support boss. Calibration of the disc enables the coolant flow to be pre-adjusted.

The load is transferred from one fuel element to the next through a male and female cone assembly, the male cone being screwed to the bottom of one fuel element, the female cone to the top of the fuel element immediately beneath. The diameter of the male cone is made greater than the overall diameter of the fins to provide protection on charging and discharging, while the diameter of the female cone is selected so that, on charging, the male cone of the descending fuel element cannot fail to enter, even if it is displaced to one side of the channel. Only the female cone has radial arms for lateral support of the fuel elements. With this arrangement, as soon as a fuel element is lifted for discharge, the lower end becomes completely free of lateral restraint. This minimises the chance of a fuel element jamming, if distortion has taken place under irradiation.

The gas temperature along the channel is considerably below that of the uranium (Fig. 4, paper by Packman and Cutts). To exploit this the finning on the fuel element is extended beyond the uranium, so as to over-cool the end of the fuel elements. This compensates for an approximate increase in neutron flux of 15 per cent at the ends of the uranium, and also means that the support cones are at a temperature nearer the gas temperature than the uranium temperature. Adequate creep strength is then obtained, using a magnesium manganese alloy. The radial arms are located low down on the female cone so that if there is any tendency for the cone to spread in creep the radial arms will not jam in the channel. The faces of the cones are graphitised during manufacture to minimise the possibility of them sticking together.

An abbreviated list of main parameters and performance of the reactor plant is given below :

Abridged List of Main Parameters and Performance Data of Reactor Plant

Reactor core :	
Fissile material, natural uranium, tonnes	130
Number of fuel element channels	1696
Diameters of fuel element channels	256 at 4·16in dia. 576 at 3·95in dia. 864 at 3·61in dia.
Pitch of channels, inches	8
Number of control rod channels	112
Diameter of control rod channels, inches	3·25
Nominal core height, feet	21
Nominal core diameter, feet	31
Height of graphite, feet	27
Diameter of graphite (across corners), feet	36
Machined weight of graphite, tons	1146
Core graphite density, g/cm³*	1·73
Core graphite absorption cross section (measured in air in GLEEP), millibarns*	4·0
Reflector graphite density, g/cm³*	1·60
Reflector graphite absorption cross section (measured in air in GLEEP), millibarns*	4·8
Uranium rod diameter, inches	1·15
Length of uranium in channel, feet	20
Density of uranium, g/cm³*	18·7
Absorption cross section of cans and supports, cm²/ft uranium	0·51
Reactor pressure vessel :	
Inside diameter, feet	37
Thickness of shell, inches	2·0
Design stress at 400 deg. Cent. (752 deg. Fah), pounds per square inch	12,000
Working pressure, pounds per square inch gauge	100
Main CO_2 ductwork :	
Numbers of ducts in parallel	4
Diameter of ducts, feet	4·5
Mean coolant velocity (hot ducts), feet per second	74
Mean coolant velocity (cool ducts), feet per second	49
Main CO_2 circulators :	
Number of circulators	4
CO_2 flow rate per circulator, pounds per second	500
Pressure rise in circulator, pounds per square inch	5·53
Isentropic efficiency at design point, per cent	78
Shaft power to circulator motor, horsepower	1,495
Electrical power required (four circulators), MW	5·44
Main heat exchangers :	
Number of heat exchangers	4
H.P. steam flow rate, pounds per hour	396,000
H.P. steam exit temperature	595 deg. Fah. (313 deg. Cent.)
H.P. steam exit pressure, pounds per square inch absolute	210
L.P. steam flow rate, pounds per hour	118,600
L.P. steam exit temperature	350 deg. Fah. (177 deg. Cent.)
L.P. steam exit pressure, pounds per square inch absolute	63
Feed water temperature	100 deg. Fah. (38 deg. Cent.)
Turbo-alternators :	
Number of sets per reactor	2
H.P. steam temperature at T.S.V.	590 deg. Fah. (310 deg. Cent.)
H.P. steam pressure, pounds per square inch absolute at T.S.V.	200
L.P. steam temperature	340 deg. Fah. (171 deg. Cent.)
L.P. steam pressure, pounds per square inch absolute	53
Flow rate to condenser per set, pounds per hour	257,300
Vacuum at turbine exhaust, inches Hg	28·25
Gross electrical output of each turbo-alternator, MW	21·0

* Used for calculations.

Reactor Pressure Vessel

The main reactor vessel was an extrapolation of previous engineering experience and so represented one upper limit in both the possible performance of the plant and in the practicability of this construction. It was, therefore, an item of plant well developed during its design study phase, and little change took place later. Its design and construction is the subject of a paper by Brown, Noone and Bishop, and brief mention of the salient points only is made here for continuity.

With site fabrication, necessitated by a vessel of this size, good weldability was an important requirement in the selection of the steel for fabrication. A fully killed steel, with high notch-ductility, manufactured to a specification which included chemical composition, physical properties, heat treatment and grain size, was selected. The steel, "Lowtem," has a carbon content of 0·12–0·16 per cent. A cut-out rate of 1¾ per cent from 1700ft of welding in the 2in thick plate at Calder has amply proved that it is a most satisfactory type of welding material. For design purposes, the maximum temperature was taken at 400 deg. Cent. (752 deg. Fah.), for which the average working stress was taken as 12,000 lb per square inch.

After careful consideration of relevant experience, 2in was selected as the thickness of plate on which the design could be based. At the ends of the vessel, this thickness was rather more than was necessary to withstand the internal pressure in the unpierced state, but the excess in some measure compensated for the openings required. The vessel consists of a vertical cylinder of 37ft internal diameter, having semi-ellipsoidal ends fabricated from pressings. Openings for the passage of gas in and out of the reactor represented a considerable design problem. The top gas-duct components include the heaviest compensation in the vessel (4½in thick plate), and the 12ft diameter hole, where the inlet manifold is attached by a forged ring to the main structure, must be one of the largest holes in a pressure vessel of this size.

Inspection of the Vessel

During the design study, an investigation was made into the residual activity of the reactor after various intervals from shut-down and discharge of the fuel elements, to see whether inspection and possibly repair were at all feasible. It was found§ that trace amounts of cobalt, with its long half-life, in the steel of the pressure vessel, was the controlling factor in residual activity, once the plant had been in commission a few months.

Steels from widely separated sources were analysed to find one which was cobalt-free, to no avail. Trace amounts were in every case present. In consequence the possibility of routine inspection, as then conceived, receded, and emphasis was placed on soundness of design and fabrication to offset this loss. With completion of the plant in sight, a second approach was made to the problem, stimulated by the necessity of defining items of plant which could be considered subject to the regulations of the Factories Acts and associated Statutory Orders, with their requirements for routine examination.

The heat exchangers, CO_2 ducting, main circulators and ancillary circuits of the reactor unit can all be inspected in accordance with current practice and legislation. With the reactor vessel, however, a departure from orthodoxy is inevitable, as direct physical access to the interior is denied. Detailed consideration revealed, however, much that could be done ; in fact, routine inspection is by no means impossible but rather more difficult and requiring the development of new techniques.

The following summarises the approach to the problem which has been introduced at the Calder Works :

(i) *Survey.*—Periodic surveys establish distortions of the graphite core, its position on the grid structure, the position of the grid structure on the inner support brackets, and any distortion or displacement of the vessel itself from its original position.

In order that these measurements may be carried out, additional branches have been included in the design for the introduction of poker gauges and optical instruments. Permanent marks have been made both inside and outside the vessel to act as reference points. Survey will also establish movement of the branches of the vessel. Analysis of these measurements will enable a thorough assessment of the geometrical state of the reactor to be made.

(ii) *Check on Irradiation Effects.*—The degree of irradiation is not expected to have much effect on the properties of the steel. Nevertheless it is obviously important to make a periodic check. For this purpose steel specimens, which include welded and prestressed types, have been placed at selected positions within the vessel, e.g. at the end of the charge branch plugs. At predetermined intervals, these are removed on a selective basis and subjected to mechanical tests. Sufficient specimens have been included to cover a twenty-year span.

(iii) *Check on Corrosion Effects.*—The steel specimens just described will be examined also for the effects of corrosion by the hot CO_2 gas. In addition, selected parts of the vessel, both inside and out, will be examined by "Introscope" and television equipment. The development of this latter equipment was started during the design study for the specific object of carrying

§ "The 1951–53 Harwell Design Study," by R. V. Moore and B. L. Goodlet. Symposium on Calder Works Nuclear Power Plant.

out internal examination of the uranium channels. Over quite extended periods of time the camera was not damaged by the residual radiation within a shut-down reactor. A very compact unit has been developed and supplied for the Calder Works, which gives a most useful picture. Further developments of the technique are to be expected.

The condition inside the shell can also be inferred by direct internal examination of the ducts associated with the reactor outside the radiation field, and of the heat exchangers.

(iv) *Detection of Leaks.*—Cooling air is induced through the vault between the main pressure vessel and the biological shield. Any leak of CO_2 will become mixed with this air. Sampling points have been installed at various positions and sensitive detection equipment has been provided for monitoring purposes. The arrangement of the sampling points is such that a general indication will be given of the area in which leakage is taking place, and further localisation of the leakage may be made by probes connected to portable monitoring equipment.

(v) *Temperature Effects.*—A comprehensive scheme of thermocouples has been installed inside and outside the vessel. A close check can thus be kept on absolute temperatures, temperature differences and rates of change to which selected parts of the vessel have been subjected during its life.

It is fully expected that as operating and inspection experience is built up, improved techniques and appliances will be developed and reflected in design to extend the scope of these inspection proposals, which are already reasonably comprehensive. The old concept that no inspection is possible is clearly not valid, and the periodic inspections will no doubt in a few years be regarded as normal routine.

Structural Design

Reactor Foundations.—The total load imposed by the walls and roof of the biological shield, and the reactor itself, is about 20,000 tons on an area about 60ft square. The allowable ground pressure being 2·5 tons per square foot, this load is spread by means of a concrete raft, rectangular in shape, 130ft by 104ft by 11ft thick. Wing walls, which were required in any case to act as radiation shielding for the main CO_2 inlet ducts, were incorporated to act as buttresses between the biological shield and the raft. The raft was designed as a slab, subject to an upward ground pressure and supported by the octagonal walls of the main shield and the wing walls. The heat-exchanger foundations and those of the circulator houses are independent of this main raft, a differential settlement of ½in being assumed in the design of the ductwork linking the pressure vessel with the heat exchangers.

Biological Shield Walls.—The reactor is surrounded by thermal and biological shields, the former of 6in mild steel and the latter of 7ft reinforced concrete. The concrete thickness is determined by shielding and not strength considerations. The dry density of the concrete shield was specified at 150 lb per cubic foot, and to achieve this it was necessary to use Winstone aggregate. Great care was taken during its construction to ensure consistent density and to avoid any cavities. The thermal and biological shields are subject to direct heating from the pressure vessel and to heating by nuclear irradiation. Heating of the thermal shield is due mainly to the absorption of gamma-radiation arising from the capture of thermal neutrons in the graphite reflector, in the pressure vessel and in the thermal shield itself. The heating effect in the biological shield is due mainly to absorption of gamma-radiation resulting from the slowing down of fast neutrons and their ultimate capture. To reduce the temperature gradient across the concrete, and limit the thermal stresses to an acceptable level, this heat is removed as described later ; the effect is such that the temperature gradient through the concrete approximates to a straight line, with a maximum drop of 30 deg. Fah. (16·7 deg. Cent.) from inside to outside face.

In plan view the shield walls form an octagon ; the surface of the walls were kept within the limits of two imaginary planes 1in apart. To achieve this, a rigid steel framework built up from angle sections was erected covering the whole area of the octagon and extending the full height. This carried vertical steel angles forming the corner profiles of the octagon and acted as guides in fixing the wall shuttering. Climbing shutters were used, made of 2in thick timber in panels 10ft wide and 4ft 6in deep, which were carried by vertical members clamped to the next lower lift of concrete using specially built-in fastenings.

Roof Design.—The design and construction of the concrete roof over the reactor was one of particular difficulty, pierced as it is by a large number of holes to accommodate the top branches of the pressure vessel, although not permitting the escape of radiation into the working spaces on top of the reactor. Further, it was not possible during construction to support the roof slab from the underside in the normal way, as propping was prevented by the presence of the reactor vessel. As the 6in steel plates of the roof thermal shield had to be placed before concrete was poured, all shuttering was left in. Lattice girders within the depth of the slab could not be tolerated as a solution because of the limited space between the holes. It was decided, therefore, to support the shuttering from Bailey girders spanning temporarily above the slab.

As the shuttering could not be recovered, it was desirable to keep it as light and as cheap as possible. This was done by limiting it to a thin steel sheet to support only a 12in thickness of concrete. When set, this concrete acted as the permanent shuttering for the remainder of the slab.

Angle sections carrying the thermal shield and the shuttering plates were supported by adjustable hangers from the Bailey girders, themselves spaced 8ft apart. The concrete was poured in four lifts, the first being 12in thick and the remainder each 2ft 4in. Only the first three lifts were considered to act structurally, so that the design of top lift could be varied as necessary to accommodate many requirements, such as cable trenches, associated with the floor details.

Rather than place restraint on the pressure vessel it was decided to allow free movement of its top branches ; clearance had therefore to be provided between them and the concrete. This gap must be stepped as an uninterrupted gap would provide a path for radiation leakage. The steel shutter tubes, which are cast-in for these holes in the roof, were jigged off the pressure-vessel branches. They were displaced eccentrically in the cold state so that maximum all-round clearance occurs under service conditions. The annular gap between pressure-vessel branches and the shutter tubes is used for the passage of air to cool the branches and provide ambient temperature conditions satisfactory for the control rod mechanisms.

Cooling of the Shield.—The considerable heat generated both in the thermal and biological shields‡ is removed by an air cooling system to avoid excessive temperatures and stresses in the concrete. The air flows in the spaces between the thermal and biological shields of the walls, floor and roof, while air in the main vault is drawn in over the charge branches of the reactor vessel, cooling them and providing a change of air in the vault to prevent a build-up of its activity. Extract fans keep the whole system under suction so that any leakage is inwards from the operating spaces around the reactor. Four extract fans are provided, arranged in pairs on opposite sides of the building immediately beneath the chimneys. One fan of each pair is stand-by plant. They are driven normally by a.c. motors but in the event of a.c. failure may be changed to d.c. motors drawing current from the guaranteed supply.

To ensure that leakage does not reduce the quantities of air flowing in any of the cooling passes, gaps between the thermal shield plates and holes through the shields are sealed. As an additional safeguard, all inlets and outlets of the system are fitted with dampers, not only to give flow adjustment but also making it possible to balance the pressure difference between passes to minimise the effect of cross-leakage. Ductwork inaccessible for repair is made robustly of aluminium to reduce corrosion effects.

‡ "Shield Design," by C. C. Horton and W. Bonsall. Symposium on Calder Works Nuclear Power Plant.

The Main Gas Circuit

The CO_2 gas enters the base of the reactor at 100 lb per square inch gauge and 140 deg. Cent. (284 deg. Fah.), and leaves the top at 336 deg. Cent. (637 deg. Fah.) in four parallel and identical circuits. Each circuit includes a heat exchanger, in which the heat is removed from the CO_2 in raising steam for the turbines, and a main circulator in the low-temperature limb. Isolation is provided by valves of the wedge-gate type in both inlet and outlet ducts and situated as close to the reactor as the radiation shielding design will permit. A 6in by-pass connection is provided across these valves, as they will not open against a difference of pressure greater than 5 lb per square inch.

During reactor operation there is a gradual build-up of Wigner energy in the graphite, particularly at the low-temperature end of the core. To release this energy from time to time, the temperature of the whole core can be raised to about 340 deg. Cent. (644 deg. Fah.). The reactor is run at low power, and hot gas is extracted from the top of the vessel and returned by an auxiliary circulator to the inlet end. Relative adjustment of this by-pass gas flow, the reactor power and the cooling facility of one of the main circuits (the remainder being isolated) will enable the release to be carried out in a controlled fashion.

The CO_2 Supply.—The CO_2 charge of the circuit and subsequent make-up is provided from a bulk liquid-CO_2 storage plant, the liquid being stored in four refrigerated vessels at a temperature of −18 deg. Cent. (0 deg. Fah.), and a pressure of 300 lb per square inch gauge. Vaporisation of the liquid CO_2 is through a steam-jacketed heat exchanger associated with each storage vessel. The full rate of production of CO_2 gas is 8 tons per hour, and the total CO_2 capacity of the main reactor circuit is 25·2 tons.

A rigid specification is laid down for the CO_2. If impurities were present they might react chemically with reactor materials or might give rise to a hazard because of the radioactivity induced in them. One of the advantages of CO_2 as a coolant is that in ordinary commercial form it is exceptionally pure, a typical specification by weight being as follows :—

Argon, p.p.m.	Nitrogen, per cent	Oxygen, per cent	Hydrogen, per cent	Water, per cent	Boron, p.p.m.
<1	<0·1	<0·1	<0·1	<0·05	<0·1

The most abundant, naturally-occurring isotope of argon, ^{40}A, irradiated with slow neutrons, yields a radioactive isotope ^{41}A by the the reaction

$$^{40}A\ (n, \gamma)\ ^{41}A$$

It can be shown that when ^{40}A is present in the CO_2 to a concentration of 10 p.p.m., the external radiation to be expected at different parts of the reactor circuit from ^{41}A is, at the most, of the same order of magnitude as that of the radiation from ^{17}N. The ^{17}N is produced by the reaction

$$^{18}O\ (n, p)\ ^{17}N$$

from the ^{18}O in the CO_2, and consequently has to be accepted. A specification of argon impurity of less than 1 p.p.m. is, therefore, satisfactory. Once the maximum argon content of the gas has been accepted at 10 p.p.m., the concentration of nitrogen is virtually set at 0·1 per cent because the nitrogen/argon ratio in air is 100 : 1, and most sources of argon in the reactor are derived originally from air, with no selective separation of the argon and nitrogen. The hazard arising from the ^{14}C produced from 0·1 per cent nitrogen irradiated for five years is negligible.

Oxygen introduced into the reactor will tend to react irreversibly with graphite at the hottest zone of the reactor, to produce CO_2. With a filling of 46,000 cubic feet (equivalent to 25·2 tons at N.T.P.), 0·1 per cent of oxygen would remove 7 kg of graphite. A hundred such fillings would remove 0·7 ton, which is a small weight loss compared with the total weight of the graphite. Again, commercial purity is acceptable.

The upper limit of water vapour concentration can be set arbitrarily at 0·1 per cent by adopting the requirement that dew should not condense out on the reactor surfaces when the gas is at full pressure, but at room temperature. Experiments have shown that neither the CO_2-graphite reaction nor the corrosion of magnesium or steel is affected adversely by concentrations ten times

this value, so that the value of 0·05 per cent, which is commercially available, lies well within the acceptable limit.

Initially (and subsequently if it has been admitted) air in the system has to be displaced by CO_2. To facilitate this, exhausters have been installed in the CO_2 discharge system which can partially evacuate the system to $^1/_{10}$ atmosphere. The argon content of the air initially filling the plant is about 1 per cent by volume. Therefore, three evacuations to $^1/_{10}$ atmosphere, followed each time by filling with CO_2 to 1 atmosphere, will reduce the argon content by 10^3 to a concentration of 10 p.p.m.

Preserving a Clean Coolant.—When the circuit has been purged, gaseous impurities can only arise from within the circuit or be inadvertently introduced, e.g. during loading and unloading uranium. At the beginning the main source of gaseous impurities is the graphite block, from which it is estimated about 10,000 cubic feet of gas other than water vapour will be slowly desorbed. The gases arising in this way, however, are a non-recurring source of impurity, and their concentration can be readily reduced by blowing down and charging the circuit with fresh CO_2. Initially as much as 0·4 lb of water may be present per ton of graphite, i.e. a total of 450 lb. Another source of water might be a very small leak in the heat-exchanger tubes, although, as described later, precise measures have been taken to minimise this possibility. To remove water vapour from these two possible sources, a small percentage of the main gas flow is continuously by-passed through duplicate drier units, consisting of two vessels filled with activated alumina absorbent, arranged so that one vessel can be reactivated by heat while the other is drying. Each unit is capable of continuously removing 1¼ lb of moisture per hour, for an outlet dew point of 0 deg. Cent. (32 deg. Fah.).

Utmost cleanliness was enforced during the construction of the plant ; even so, solid particles of graphite and iron oxide dust are bound to arise within the CO_2 circuit, and may become entrained in the gas stream. Such particles become irradiated if they arise in or pass through the reacting core. To prevent a concentration of these solid particles, a random 2 per cent of the gas flow is continuously filtered. Cyclones are fitted in two of the main gas circuits and porous ceramic filters in the remaining two. The filters are designed to give 100 per cent efficiency down to 10 μ particles, and can be blown back periodically for cleaning purposes. These alternative systems—cyclones or filters—were provided, as it was almost impossible to predict the quantity and size of the solid arisings, and the installation of two systems will give opportunity for operational experience to show a preference.

Finally, since the fuel element cans are liable to damage at high temperatures if contaminated by a number of materials, including lead, aluminium and copper,† these materials were meticulously excluded from any part of the CO_2 pressure circuit, both in the design and subsequently during construction.

Discharge of CO_2.—The discharge of the CO_2 from the system to atmosphere is effected through porous ceramic filters to remove any entrained solid products. As already noted, significant activities created by the neutron bombardment of the cooling gas will be ^{16}N, ^{41}A and ^{14}C, arising respectively from the oxygen in the CO_2 and from the argon and nitrogen present as impurities. With the upper limit of concentration adopted, ^{16}N and ^{41}A in the gas stream will reach equilibrium values of 8 c and 17 c in approximately thirty seconds and six hours respectively, while the ^{14}C will build up linearly, reaching a value of 13 c at the end of five years. It can be shown that no hazard will arise at ground level from discharge of this activated gas, in the way designed.

The Safety Valves.—The remaining components in the CO_2 circuit are the safety valves. Excess pressure in the CO_2 circuit can arise from three causes :

(i) Overheating the reactor ;
(ii) Overcharging with CO_2 ;
(iii) Steam and/or water leaking into the gas circuit from the heat exchangers.

Protection is provided to eliminate the possibility of (i) and (ii) happening, but (iii) could occur if, for example, a heat-exchanger tube punctured, and safety valves are consequently provided. Since the four heat-exchanger vessels are connected to the reactor vessel by gas ducts which include isolating valves which might be closed, each vessel has been fitted with its safety-valve unit. This consists of two safety valves preceded by isolating valves which enable them to be maintained in service. Thus the complete system includes ten safety valves, one pair to each heat exchanger, and one pair to the reactor vessel. A single handwheel is provided for the ten isolating valves, so that only one valve can be closed at a time. The safety valves are set at 15 per cent above normal working pressure, i.e. 115 lb per square inch gauge, and are of the full-bore, high-lift type. The capacity of one safety valve has been calculated to relieve the rise in pressure from a fracture of an h.p. evaporator tube when the steam side is at a pressure of 200 lb per square inch gauge, and the gas side is isolated and at the operating temperature and pressure. Normally, two such valves would operate in parallel whereas with the isolating valves open, the full number would be available.

† "Metallurgical Developments," by L. Grainger and A. B. McIntosh. Symposium on Calder Works Nuclear Power Plant.

Reactor Conference at Harwell

Two hundred representatives of British industry and electricity supply attended a conference at the Atomic Energy Research Establishment, Harwell, on November 30, when members of the staff of the U.K. Atomic Energy Authority described their development work on advanced types of nuclear reactors. To open the conference Sir John Cockcroft, the director of the Research Group of the Authority, outlined the present stage of reactor research, and pointed out that the continually advancing knowledge of reactor technology would inevitably cause changes in emphasis and intention in the future. Sir John then referred to the large-scale nuclear power programme given in the White Paper of February, 1955, and enumerated the main objectives of each stage of the reactor power programme. The objective of the first stage of the programme was, he said, to reduce the capital cost of gas-cooled reactors by increasing the efficiences and the heat ratings of these reactors. Fuel elements to withstand higher temperatures were being developed. These present problems, which were mainly metallurgical, were being vigorously attacked. The aim of the second stage programme was to develop a nuclear reactor with appreciably lower cepital costs than the gas-cooled reactor. To achieve this, liquids might be used as heat transfer media. The fuel would be initially enriched with plutonium created in the first stage reactors, but, after the initial charge, it should prove possible to recycle the plutonium through the reactor.

The papers presented were largely concerned with the later stages of the programme outlined in the White Paper of February, 1955. Mr. L. Rotherham read a paper on one of the possible second stage reactors, the sodium-graphite reactor system. He said that the technical feasibility of this system was not in doubt, but that a great deal of work remained to be done on the development of fuel elements, on the design of the heat transfer system and on protecting the graphite against the liquid sodium. The other system under study for this stage was the pressurised water reactor. The third stage of the reactor research programme was concerned with the development of reactors with high conversion coefficients in which fuel costs would be reduced to a low value. The high ratings of these reactors should also markedly reduce capital costs.

Dr. P. Fortescue gave an account of the work now in progress on the high-temperature gas-cooled reactor. The aim of this system was to achieve really high temperatures of operation (700–800 deg. Cent.) by using an almost homogeneous type of fuel element in which the fuel and moderator would be very closely packed together, possibly in ceramic type elements. In this way the heat transfer problem would be eliminated.

Mr. R. Hurst gave an account of the problems involved in the design of 100MW homogeneous aqueous reactor. In this system some of the more difficult problems were associated with the continuous fuel processing techniques which might be used and with the handling of the blanket "slurries." Similar problems were described by Mr. J. Smith in a paper on the liquid-metal-fuelled reactor, in which bismuth may be used as the solvent metal ; both these reactors would resemble large-scale chemical plants rather than conventional reactor systems. One very important problem in the development of the liquid-metal-fuelled reactor was the development of a graphite moderator which would be impermeable ; it was possible that a beryllium moderator might have to be used.

The present advanced state of the work on fast reactors in the third stage of this programme was described by Mr. H. Cartwright. He emphasised that although the Dounreay experiment would go critical in the first half of 1958, that would be only the beginning of an extensive experimental programme aimed at obtaining the nuclear, metallurgical and engineering data required to design a prototype fast power reactor. Although the engineering problems of design were considerable it was in the metallurgical field that most work needed to be done to be able to derive full advantage from a fast reactor system.

Harwell is investigating possible propulsion reactor systems in collaboration with the British Shipbuilding Research Association. One of the more promising of these systems, the organic liquid moderated reactor, is being looked at also as a candidate for power reactors with outputs between 10MW and 30MW of electricity for the export market. Mr. H. W. Bowker presented a paper on this system, in which it was pointed out that one of its principal advantages was the low pressure and higher operating temperature compared with those of the pressurised water reactor. The corrosion problems involved should be less severe than in other liquid systems and the rate of deterioration of possible organic liquids under irradiation was not sufficiently fast to make the system uneconomic.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

RUBBER TUBING AND BUNGS FOR LABORATORY USE

No. 2775 : 1956. Price 3s. This new standard was prepared primarily to reduce the variety of sizes of rubber tubing at present being used in laboratories. Only metric sizes have been standardised, as a large proportion of laboratory equipment is now based on metric dimensions. The sizes provided should be adequate for most normal purposes, even where inch dimensions are used. Three thicknesses of tubing are provided for : normal wall tubing, medium wall tubing and thick wall tubing. The term "pressure tubing" for thick wall tubing is deprecated, as unlined rubber tubing is intended for use only at relatively low pressures. Two sizes of analytical tubing are provided for. The tube with the smaller bore is to be made of either natural or synthetic rubber ; that with the larger bore is to be made of natural rubber. The standard specifies the physical requirements of rubber bungs for laboratory use. Although endeavours were made to standardise the sizes of these bungs, it was found impracticable to do so owing to the great variety of sizes in current production.

GLOSSARY OF TERMS FOR CONCRETE AND REINFORCED CONCRETE

No. 2787 : 1956. Price 7s. 6d. Some 700 terms and definitions relating to the design, constituent materials, mixing, placing and testing of concrete and reinforced concrete are given in alphabetical order within the forty pages of this British Standard glossary. The glossary is the first in a series which the Institution is preparing to cover the terms used in the building and associated industries. Although the glossary is arranged alphabetically throughout, reference to it has been additionally simplified by the inclusion of a number of groups of definitions, e.g. "Cement," "Reinforcement" ; where this arrangement has been adopted, terms appearing in their normal alphabetical sequence bear a cross reference to the group concerned. Owing to the rapid advances being made in the technology of prestressed concrete, only a limited number of terms are included in this subject.

Research on Automobile Stability

No. II—(*Continued from page 776, November 30*)

The Flight Research Department of the Cornell Aeronautical Laboratory has for many years been engaged on the performance of full-scale research on the stability and control of aircraft. A development contract was undertaken for General Motors Research Staff to secure a better understanding of the directional stability and control of automobiles. The lack of flat-road tyre data of a form and completeness suitable for stability and control analyses led to the development of a six-component tyre testing apparatus under a contract with the U.S.A.F.

The Dimensional Equations of Motion

If one uses an alternate notation $\left(Y_\beta = \frac{\partial Y}{\partial \beta}, \text{&c.}\right)$ the dimensional equations of motion of an automobile can be expressed as :

$$MV(\dot{\beta}+r)+M_s hp = Y_\beta\beta + Y_r r + Y_\delta\delta + Y_\phi\phi \quad . \quad (35)$$

$$I_x\dot{r}+I_{xz}\dot{p} = N_\beta\beta + N_r r + N_\delta\delta + N_\phi\phi + N_p p \quad . \quad . \quad (36)$$

$$I_{xz}\dot{p}+M_s hV(\dot{\beta}+r)+I_{zz}\dot{r} = L_p p + L_\phi\phi \quad . \quad . \quad . \quad (37)$$

where

$$Y_\beta = C_1 + C_2 = C$$

$$Y_r = C_1\frac{a}{V} - C_2\frac{b}{V}$$

$$Y_\delta = -C_1$$

$$Y_\phi = -\varepsilon_s C_s + \frac{\partial Y_1}{\partial \phi}$$

$$N_\beta = aC_1 - bC_2 + \frac{\partial AT}{\partial \alpha_1} + \frac{\partial AT}{\partial \alpha_2} + \frac{\partial X}{\partial Z}(C_1 z_1 + C_2 z_2)$$

$$N_r = C_1\frac{a^2}{V} + C_2\frac{b^2}{V} + \frac{\partial AT}{\partial \alpha_1}\frac{a}{V} - \frac{\partial AT}{\partial \alpha_2}\frac{b}{V} + \frac{\partial X}{\partial Z}\left(\frac{z_1 C_1 a}{V} - \frac{z_2 C_2 b}{V}\right)$$

$$N_\delta = -aC_1 - \frac{\partial AT}{\partial \alpha_1} - \frac{\partial X}{\partial Z}z_1 C_1$$

$$N_\phi = b\varepsilon_2 C_2 - \frac{\partial AT}{\partial \alpha_2}\varepsilon_2 + a\frac{\partial Y_1}{\partial \phi} - \frac{\partial X}{\partial Z}\left(z_2 C_2 \varepsilon_2 - k - z_1\frac{\partial Y_1}{\partial \phi}\right)$$

$$N_p = \frac{\partial X}{\partial Z}L_p$$

$$L_p = \left(\frac{\partial L}{\partial p}\right)_1 + \left(\frac{\partial L}{\partial p}\right)_2$$

$$L_\phi = W_s h + k_1 + k_2 = W_s h + k$$

The use of the stability-derivative concept to express the external forces and moments acting on an automotive vehicle may be further clarified by an examination of the forces and moments that arise when the car is experiencing motion in one degree of freedom only. Consider, for example, the automobile to be side slipping to the right, as is indicated in Fig. 4. (For simplicity, incremental drag forces resulting from load transfer have been omitted.) Since $C = \partial Y/\partial\alpha$ is a negative quantity by definition, because of the choice of axis system, a force to the left appears when the car possesses a lateral velocity along the positive y axis. This force always opposes the motion and thus Y_β may be considered a damping derivative.

The direction of the yawing moment produced by the cornering forces, however, is critically dependent on the centre of gravity location and the relative magnitude of the front and rear cornering powers. Forward centre of gravity locations and rear cornering power higher than front cornering power result in a positive yawing moment for a positive angle of side slip, while the reverse is true for rearward centre of gravity locations and low values of rear cornering power relative to front cornering power. (Note that pneumatic trail has the effect of moving the centre of gravity forward with respect to the tyre reactions, and thereby produces a positive yawing moment. It is more convenient, however, to show tyre forces at the wheel centre and introduce a corresponding aligning torque.)

If the total yawing moment produced by side slipping is such as to reduce the angle of side slip, the vehicle may be said to be directionally stable and if the total yawing moment is such as to increase the angle of side slip, the vehicle may be said to be directionally unstable. The stability derivative N_β is thus called the "directional stability" or the "directional stiffness." It is seen that this stability is identical to the weathercocking stability of a weathervane or the directional stability provided by the vertical tail on an aeroplane. In the case of a four-wheeled vehicle, the rear tyres provide a stabilising moment, while the front tyres provide a destabilising moment. Note that this attitude stability is merely a property of a vehicle which is side slipping. While N_β does influence the dynamic behaviour, it does not provide positive indication of dynamic stability.

In a similar fashion, the remaining stability derivatives possess physical significance. Thus, Y_δ and N_δ, which are the side force and yawing moment produced per unit steering angle of the front wheels are the "control effectiveness" derivatives. Increases in Y_δ and N_δ alone will increase the response of the vehicle to steering inputs. The derivatives, Y_ϕ and N_ϕ, are essentially "roll and camber steer" derivatives, in which side force and yawing moments are produced proportional to (1) the roll-steer properties of the rear suspension, and (2) the camber angle of the front wheels caused by roll of the rolling mass. Since in the steady state turn a fixed roll angle is produced along with the resultant angle of side slip, the derivative N_ϕ has directional stability properties similar to N_β. The derivatives L_ϕ and L_p determine the rolling behaviour of the car and are properly termed the "roll stiffness" and "damping-in-roll." Finally, one of the more important derivatives is N_r, the "damping-in-yaw." The yawing moment produced by yawing velocity always opposes this angular velocity as shown in Fig. 5. Note that the front and rear aligning torques act in opposite directions and, hence, tend to cancel one another. The yawing moment produced by the resultant cornering forces is negative for a positive yawing velocity r.

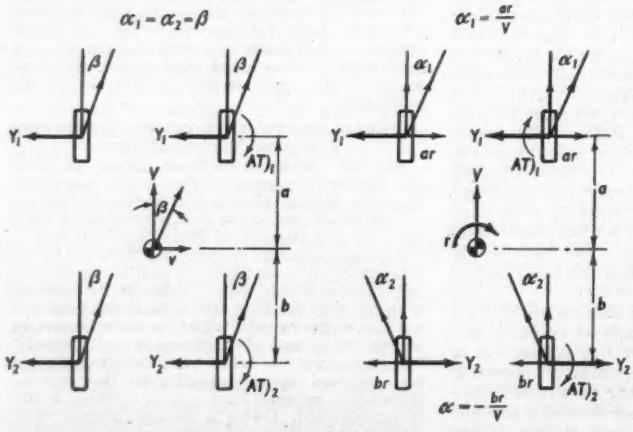


Fig. 4 (left)—Side force and yawing moment created by a side-slipping vehicle. Fig. 5 (right)—Yawing moment produced by yawing velocity

Since the induced slip angles at the front and rear tyres are inversely proportional to the forward velocity V, the damping-in-yaw, N_r, decreases as forward velocity increases. It is also seen that increasing the wheelbase is an effective means of increasing the damping-in-yaw.

A numerical evaluation of the stability derivatives, for the test vehicle used in this study, has shown that certain terms are quantitatively negligible. Although all terms in the static directional stability N_β, must be retained, those terms in the yaw damping derivative N_r, caused by aligning torque and load transfer may be neglected. Certain simplifications take place in N_δ and N_ϕ as well. The derivative N_p results only from consideration of the effects of load transfer and does not appear to be important enough to retain in the equations of motion.

The Non-Dimensional Equations of Motion

The utility of the derivatives for comparing the stability characteristics of various vehicles, regardless of physical differences, is considerably enhanced through non-dimensionalisation of the above derived equations of motion. In the non-dimensionalisation scheme selected as having the most merit, the side force equation was divided by the total weight of the vehicle and the moment equations were divided by the product of the weight and the wheelbase.

The resulting non-dimensional equations of motion deal with force and moment coefficients, together with non-dimensional velocities rather than with absolute forces, moments and velocities. For example, $\hat{r}$ is the non-dimensionalised form of the yawing velocity, r. The non-dimensionalised derivative is indicated by a lower case letter (for example, the side force coefficient produced by side slipping is y_β). Also, with this scheme, the two parameters, μ and τ, are obtained. The former proves to be the Froude number and may be considered as the non-dimensional value of forward velocity, or as the ratio between the inertia and gravitational forces of the system. The second parameter, τ, is a dimensional time constant that conveniently removes time from the dimensional equations. Further, the moments of inertia reduce to their respective radii of gyration ratioed to the reference length parameter which is the wheelbase l.

Accordingly, the non-dimensional equations of motion, with the input forces and moments placed on the right-hand side, are :

Side force equation :

$$(\mu D - y_\beta)\beta + (\mu - y_r)\hat{r} + (mD^2 - y_\phi)\phi = y_\delta\delta \quad . \quad . \quad (38)$$

Yawing moment equation :

$$(-n_\beta)\beta + (i_{zz}D - n_r)\hat{r} + (i_{xz}D^2 - n_\phi)\phi = n_\delta\delta \quad . \quad . \quad (39)$$

Rolling moment equation :

$$(m\mu D)\beta + (i_{xz}D + m\mu)\hat{r} + (i_x D^2 - l_p D - l_\phi)\phi = 0 \quad (40)$$

where

$$\tau = \sqrt{l/g}$$

$$D = \tau\frac{d}{dt}$$

$$\hat{r} = \tau r$$

$$\mu = V/\sqrt{lg}$$

$$m = \frac{M_s h}{Ml}$$

$$i_{xz} = \frac{M_s hc}{Ml^2}$$

$$i_x = \frac{I_x}{Ml^2}$$

$$i_s = \frac{I_s}{Ml^2} = \left(\frac{k_z}{l}\right)^2$$

$$y_\beta = \frac{Y_\beta}{Mg} = \frac{C}{Mg}$$

$$y_r = \frac{Y_r}{M\sqrt{lg}} = -\frac{C}{Mg}\frac{1}{\mu}\left(\frac{C_2}{C} - \frac{a}{l}\right)$$

$$y_\phi = \frac{Y_\phi}{Mg} = -\frac{C}{Mg}\left(\varepsilon_2\frac{C_2}{C} - \frac{\partial Y_1/\partial\phi}{C}\right)$$

$$y_\delta = \frac{Y_\delta}{Mg} = -\frac{C}{Mg}\left(1 - \frac{C_2}{C}\right)$$

$$n_\beta=\frac{N_\beta}{Mlg}=-\frac{C}{Mg}\left[\frac{C_2}{C}-\frac{a}{l}-\frac{\partial AT/\partial\alpha_1+\partial AT/\partial\alpha_2}{Cl}-\frac{\partial X}{\partial Z}\left(\frac{z_1}{l}+\frac{z_2-z_1}{l}\frac{C_2}{C}\right)\right]$$

$$n_r=\frac{N_r}{Ml\sqrt{lg}}=-\frac{1}{\mu}\frac{C}{Mg}\left[\frac{C_2}{C}\left(\frac{2a}{l}-1\right)-\left(\frac{a}{l}\right)^2\right]$$

$$n_\phi=\frac{N_\phi}{Mlg}=-\frac{C}{Mg}\left(-\frac{C_2}{C}\varepsilon_2\frac{b}{l}-\frac{a}{l}\frac{\partial Y_1/\partial\phi}{C}-\frac{\partial X}{\partial Z}\frac{k}{Cl}\right)$$

$$n_\delta=\frac{N_\delta}{Mlg}=-\frac{C}{Mg}\left[\frac{a}{l}\left(1-\frac{C_2}{C}\right)+\frac{\partial AT/\partial\alpha_1}{Cl}\right]$$

$$l_p=\frac{L_p}{Ml\sqrt{lg}}$$

$$l_\phi=\frac{L_\phi}{Mlg}=\frac{W_s h+k}{Mlg}$$

In this listing of the non-dimensional stability derivatives three physically significant parameters appear again and again. These are :—

(1) The total cornering coefficient of the vehicle, $-C/Mg$.
(2) The centre of gravity location, a/l, and
(3) The ratio of rear to total cornering power, C_2/C.

While stability parameters such as rear roll steer ε_2, front wheel camber thrust $\partial Y_1/\partial\phi$, &c., do have an appreciable influence on the directional behaviour of an automotive vehicle, the basic stability parameters of an automobile, exclusive of its mass and inertia characteristics, are these three quantities. An examination of all the constants appearing in the equations of motion reveals that a total of twenty properties of the simplified automobile must be known in order to predict its dynamic lateral motions. These properties fall into the following three categories :—

(1) Mass and inertia characteristics,
(2) Chassis or suspension properties, and
(3) Tyre characteristics.

Solution of the Equations of Motion

To compute the response to front wheel angle inputs, the derived equations of motion must be solved simultaneously by either classical or operational methods. Since the derived equations are linear differential equations with constant coefficients, the techniques of operational calculus are particularly suited for this task. If the automobile is assumed to possess zero initial lateral motion, application of the Laplace transform to equations (38), (39) and (40), in accordance with the procedure described in Gardner and Barnes (1942) yields

$$\begin{bmatrix}\mu s-y_\beta & \mu-y_r & ms^2-y_\phi\\ -n_\beta & i_z s-n_r & i_{zx}s^2-n_\phi\\ m_\mu s & i_{zx}s+m_\mu & i_z s^2-l_p s-l_\phi\end{bmatrix}\begin{bmatrix}\beta(s)\\ r(s)\\ \phi(s)\end{bmatrix}=\begin{bmatrix}y_\delta\delta(s)\\ n_\delta\delta(s)\\ 0\end{bmatrix} \quad . \quad . \quad . \quad . \quad . \quad (41)$$

The solution of the original differential equations has now been reduced to the solution of a set of algebraic equations. If one uses determinants the solution for $\beta(s)$, for example, becomes

$$\beta(s)=\frac{\begin{vmatrix} y_\delta & \mu-y_r & ms^2-y_\phi\\ n_\delta & i_z s-n_r & i_{zx}s^2-n_\phi\\ 0 & i_{zx}s+m_\mu & i_z s^2-l_p s-l_\phi\end{vmatrix}}{\begin{vmatrix}\mu s-y_\beta & \mu-y_r & ms^2-y_\phi\\ -n_\beta & i_z s-n_r & i_{zx}s^2-n_\phi\\ m_\mu s & i_{zx}s+m_\mu & i_z s^2-l_p s-l_\phi\end{vmatrix}}\delta(s) \quad (42)$$

The time response of β is found upon application of the inverse Laplace transformation. Thus,

$$\beta\left(\frac{t}{\tau}\right)=L^{-1}[\beta(s)] \quad . \quad . \quad . \quad . \quad (43)$$

where L^{-1} is the symbol for the inverse Laplace transformation.

Similarly, the steady-state response of a vehicle to a sinusoidal input of front wheel angle δ is obtained by replacing the Laplace argument, s, by the quantity $j\omega\tau$, where $\omega\tau$ is the non-dimensional circular frequency. This steady-state response is called the frequency response. For example, the yawing velocity frequency response is expressed as follows :—

$$\frac{\dot r(j\omega\tau)}{\delta(j\omega\tau)}=\frac{\begin{vmatrix} j\omega\tau-y_\beta & y_\delta & -m(\omega\tau)^2-y_\phi\\ -n_\beta & n_\delta & -i_{zx}(\omega\tau)^2-n_\phi\\ m_\mu j\omega\tau & 0 & -i_z(\omega\tau)^2-l_p j\omega\tau-l_\phi\end{vmatrix}}{\begin{vmatrix}\mu j\omega\tau-y_\beta & \mu-y_r & -m(\omega\tau)^2-y_\phi\\ -n_\beta & i_z j\omega\tau-n_r & -i_{zx}(\omega\tau)^2-n_\phi\\ m_\mu j\omega\tau & i_{zx}j\omega\tau+m_\mu & -i_z(\omega\tau)^2-l_p j\omega\tau-l_\phi\end{vmatrix}} \quad . \quad . \quad . \quad . \quad . \quad (44)$$

Experimental Substantiation of the Level Road, Fixed Control Equations

Stability Parameter Measurements.—A 1953 Buick Super was used as the test vehicle in this programme. First, in order to derive the mathematical model it was necessary to evaluate the stability parameters. Accordingly a test programme was performed to determine the rolling and yawing moments of inertia, total weight and longitudinal centre of gravity position of the instrumented car, the non-rolling weight, roll spring rates, rear roll steer, roll damping, front wheel camber due to body roll and height of the front and rear roll centres.

The pneumatic tyre derivatives for steady-state response were obtained from drum test, suitably corrected to flat road conditions in accordance with Bull (1939). Although tyre dynamics or lag in force build-up do have some effect on the vehicle response, it is small in the particular frequency range considered and was neglected in the mathematical model.

Response Test Methods.—The test car was instrumented to permit dynamic recording of the eight variables listed in Table I. The total

Table I—*Measured Variables*

Variable of motion	
Left front wheel position	δ_L
Right front wheel position	δ_R
Steering wheel position	δ_s
Lateral acceleration	n_y
Roll attitude	ϕ
Pitch attitude	θ
Angular yaw velocity	r
Angular roll velocity	p
Forward velocity	V

lateral acceleration is denoted by the symbol n_y and is comprised of the linear acceleration $\dot v$, the centrifugal acceleration Vr, and a component of gravity caused by the roll angle ϕ.

To substantiate the theory as extensively as possible, response data were obtained for as wide a range of stability conditions as was practical. Data were therefore obtained in tests wherein the following stability parameters were varied :—

(1) Forward velocity (V),
(2) Directional stability (N_β),
(3) Roll stiffness (L_ϕ), and
(4) Total cornering coefficient (C/Mg).

A complete check of the theory was obtained by measuring all three lateral degrees of freedom and comparing the response in each degree of freedom to that predicted by theory.

Such comparisons are shown in Figs. 6 and 7 ; the solid lines in these plots are the theoretical results which are shown superimposed upon two sets of test results.

The agreement is good between theoretical and practical results for all degrees of freedom ;

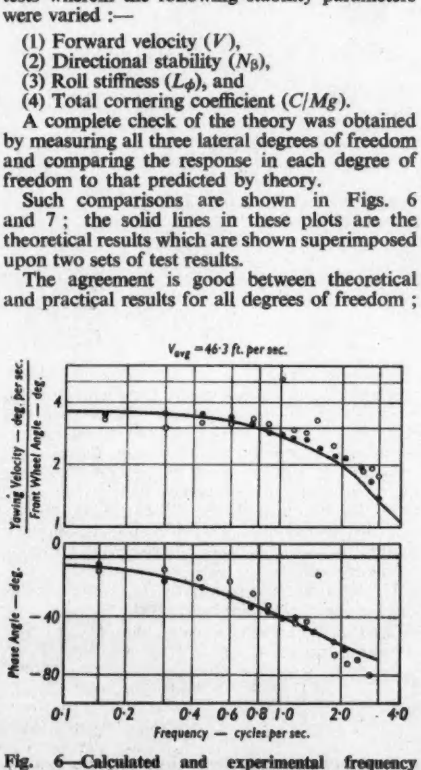


Fig. 6—Calculated and experimental frequency response—yawing velocity

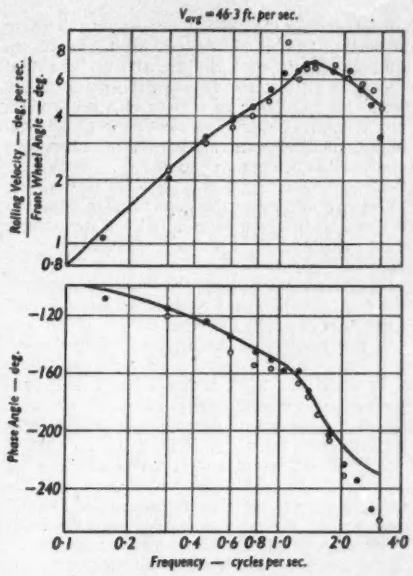


Fig. 7—Calculated and experimental frequency response—rolling velocity

however, above 2 c/s there appears to be some divergence. At high-frequency steering inputs very little response occurs as the phase lag between the front wheel angle and the yawing velocity approaches 90 deg.

The Response of the Fixed-Control Automobile to Steering Input

Steady State Response.—A solution of the equations of motion reveals that the vehicle response to steering inputs is composed of :

(1) A transient response, during which the vehicle experiences angular and lateral accelerations, and

(2) A steady state response, in which the centrifugal force arising in the steady turn is balanced by the resulting tyre forces.

These may be studied individually. Vehicle response to a fixed steering input is called the "static sensitivity" of the vehicle and as such is an important aspect of the overall behaviour of the vehicle. It is this aspect of the stability and control characteristics of the automobile which is examined first.

During a steady turn produced by a fixed displacement of the front wheels, an automobile possesses :

(1) A constant turning rate or yawing velocity ;
(2) A fixed roll angle, and
(3) A fixed angle of side slip.

In the moment equilibrium established in the turn, it is the steering moment $N_\delta\delta$ that primarily balances the yaw-damping moment $N_r r$, since the moments caused by side slip and roll angle are small and often are zero.

A solution of the equilibrium equations of motion yields the following equations for yawing velocity response :

$$\left(\frac{r}{\delta}\right)_{ss}=\frac{V/l}{1+KV^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (48)$$

where

$$K=\frac{1}{lg}\left[\frac{\dfrac{n_\beta}{y_\beta}-\dfrac{mn_\phi}{l_\phi-my_\phi}}{n_\delta-y_\delta\dfrac{n_\beta}{y_\beta}}\right]\left[\frac{1}{1-\dfrac{my_\phi}{l_\phi}}\right] \quad . \quad . \quad (49)$$

The sign of K can be negative or positive, depending on the sign of both the directional stiffness, n_β, and the yawing moment due to roll, n_ϕ. Since n_β is the non-dimensional yawing moment due to side slip, and y_β is the non-dimensional side force due to side slip, the term $n_\beta/-y_\beta$ is the effective non-dimensional distance between the centre of reaction of the tyre forces and the centre of gravity of the vehicle. It is thus seen that this moment arm, expressed a

percentage of the wheelbase, is an alternate method of defining the directional stability of an automobile. It shall suffice to say here that $n_\beta/-y_\beta$ is the distance between the neutral steer point and the centre of gravity of a non-rolling vehicle and, as such, represents the directional stiffness or the "static margin" of a non-rolling vehicle as defined in an earlier paper by Walker (1950).

The second term in the numerator of equation (49) represents a contribution to the static margin of the vehicle by the roll steer and camber thrust effects.

This numerator is, thus, the total static margin of an automobile, and is a numerical measure of the total directional stiffness.

At this point it is desirable to relate "oversteer" and "understeer" as defined by Olley, to the static margin as discussed here. It is seen that an oversteer vehicle possesses a negative and an understeer vehicle a positive static margin or directional stiffness. It is also seen that if $1+KV^2$ is set equal to zero the steady state response theoretically becomes infinite. Practically, however, the skid force capacity of the tyres prevents this condition from being attained.

The experimental results for the Buick in Fig. 8 show good correlation with the theoretical

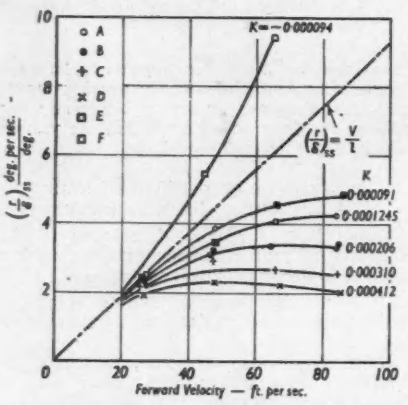


Fig. 8—Experimental steady-state response of the instrumented 1953 Buick showing the influence of static margin

curves for the five tested configurations. It was therefore concluded that equation (48) adequately describes the vehicle steady-state behaviour for lateral accelerations below 0·3 g.

Dynamic Stability and Vehicle Modes of Motion.—The characteristic equation of the automobile as obtained from the derived equations of motion can be expressed as :

$$s^4+\frac{B}{A}s^3+\frac{C}{A}s^2+\frac{E}{A}s+\frac{F}{A}=0 \quad . \quad . \quad (51)$$

where

$$A=\mu(i_z i_x-i_{xz}m^2-i^2_{xz})$$

$$B=\mu(m^2n_r-i_z l_p-n_r i_z-mi_{xz}y_r)-y_\beta i_z-y_\beta i^2_{xz}-i_{xz}mn_\beta$$

$$C=\mu(n_r l_p+n_\beta i_z+mi_z y_\phi-i_x l_\phi-n_\beta m^2+i_{xz}n_\phi+ml_{xz}y_\beta)+y_\beta i_x l_p+y_\beta n_r i_z-n_\beta y_r i_x$$

$$E=\mu(n_r l_\phi-n_\beta l_p+mn_\phi y_r-my_\phi n_r)+y_\beta l_\phi i_z-y_\beta n_r l_p+n_\beta y_r l_p+i_{xz}n_\beta y_\phi-i_{xz}y_\beta n_\phi$$

$$F=\mu(mn_\beta y_\phi-my_\beta n_\phi-n_\beta l_\phi)+n_\beta l_\phi y_r-y_\beta n_r l_\phi$$

In order that the automobile be dynamically stable—that is, the real parts of all roots are negative—a necessary but not sufficient condition is that all of the above coefficients be positive. Numerical studies for the automobile have shown that the stability is a critical function of the constant term F/A, which changes sign under certain conditions. Since the coefficient A is always positive, the dynamic stability is determined by the sign of the coefficient F. When F is positive all roots have negative real parts, and when F is negative one unstable mode of motion appears.

Note that this coefficient F, as yielded by the expansion of the characteristic determinant, is associated with the steady state solution of the equations of motion. For example :

$$\left(\frac{r}{\delta}\right)_{ss}=\frac{1}{\tau}\left[\frac{l_\phi(y_\beta n_\beta-n_\beta y_\beta)}{F}\right] \quad . \quad . \quad . \quad (52)$$

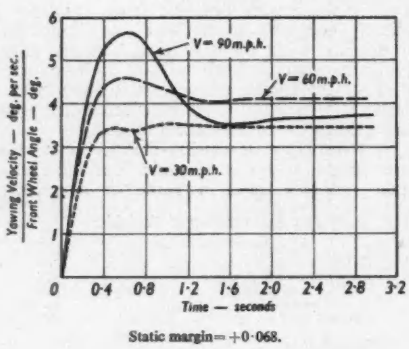
Thus, the boundary between stability and instability (that is $F=0$) is identically equivalent to the condition in which the steady-state response becomes infinite. It should be recalled that this situation occurs at that speed at which the damping-in-yaw is reduced to the point at which it is effectively cancelled by negative directional stiffness and a positive control input, therefore, produces an infinite response.

$$F=\mu l_\phi y_\beta\left[\left(1-\frac{my_\phi}{l_\phi}\right)\text{S.M.}-\frac{lg(\mu n_r)}{V^2}\right] \quad . \quad (54)$$

where

$$\mu n_r=-\frac{C}{Mg}\left[\frac{C_2}{C}\left(\frac{2a}{l}-1\right)-\left(\frac{a}{l}\right)^2\right]$$

Equation (54) shows that F can become negative only when the static margin is negative, and that for increasing speeds, an unstable static margin must become less unstable in order to maintain dynamic stability. It should be noted that the quantity within the brackets



Static margin = +0·068.

Fig. 9—Influence of forward velocity on the yawing velocity transient response of an understeer vehicle

varies as the square of the forward velocity and that, if it is set equal to zero, it is equivalent to the steady-state criterion for infinite response, i.e. $1+KV^2=0$.

Although the close proximity in frequency makes it very difficult to factor accurately the quartic into two quadratics, one for each mode, an approximate factorisation yields the following result :—

$$s^4+\frac{B}{A}s^3+\frac{C}{A}s^2+\frac{E}{A}s+\frac{F}{A}\simeq(s^2+bs+k)(s^2+b's+k') \quad . \quad . \quad . \quad . \quad . \quad (55)$$

where

$$b=-\left(\frac{y_\beta}{\mu}+\frac{n_r}{i_z}\right)$$

$$k=\frac{y_\beta n_r}{\mu i_z}+\frac{n_\beta}{i_z}+\frac{n_\phi m y_\beta}{i_z l_\phi}$$

$$b'=-\frac{l_p}{i_x-m^2}$$

$$k'=-\frac{l_\phi}{i_x-m^2}$$

Examination of these two second-order modes, represented by the two quadratic factors of the original fourth-order system, reveals that the first quadratic is identical to the characteristic equation yielded by a non-rolling automobile, whereas the coefficients of the second quadratic factor consist only of vehicle roll parameters, l_ϕ, l_p, i_x, and m. This result does indeed indicate that the first mode is a yawing and side-slipping mode, while the second is primarily a rolling mode of motion.

If attention is directed to the roots of the yawing and side-slipping mode, it is found numerically that these roots simplify to the following form :—

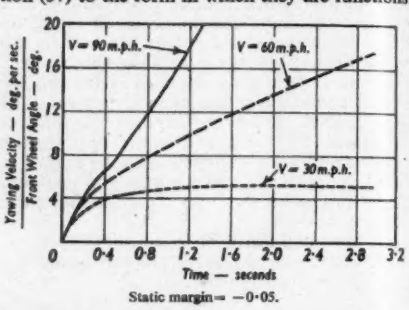
$$\lambda_1,\lambda_2=\frac{1}{\tau}\left[\frac{1}{2}\left(\frac{y_\beta}{\mu}+\frac{n_r}{i_z}\right)\pm\sqrt{n_\beta+\frac{n_\phi m y_\beta}{l_\phi}}\right] \quad (56)$$

If one refers to the definition of static margin for a rolling vehicle, it is seen that equation (56) may be rewritten, with the assumption that my_ϕ is negligible in comparison with l_ϕ, to result in the following expression for the roots λ_1 and λ_2 :

$$\lambda_1,\lambda_2=\frac{1}{\tau}\left[\frac{1}{2}\left(\frac{y_\beta}{\mu}+\frac{n_r}{i_z}\right)\pm\sqrt{\frac{y_\beta(\text{S.M.})}{i_z}}\right] \quad . \quad . \quad (57)$$

Equation (57) shows that the expression $S.M.=0$ is the boundary condition between an oscillatory mode and two distinct aperiodic modes of motion. Generally speaking, when the vehicle is understeer (static margin is positive), the complete characteristic quartic has two conjugate complex roots. When the vehicle is oversteer, there is one conjugate complex root and two real negative roots. As speed of the oversteer vehicle is increased, however, one negative real root approaches zero and eventually becomes positive at the instant the coefficient F of the characteristic equation becomes negative. Note that the damping of the directional mode is produced by the damping-in-side-slip, y_β, and the damping-in-yaw, n_r. Equation (57) shows that behaviour of the directional mode will vary widely as the static margin goes from positive to negative and as the damping decreases with increasing forward velocity of the vehicle.

Transforming the roots represented by equation (57) to the form in which they are functions



Static margin = −0·05.

Fig. 10—Influence of forward velocity on the yawing velocity transient response of an oversteer vehicle

of the basic dimensional properties of a vehicle proves to be extremely informative and enlightening. If the excellent approximation is made that $n_r=y_\beta/4\mu$, equation (57) may be written as

$$\lambda_1\lambda_2=\frac{1}{2}\frac{C}{MV}\left[1+\frac{1}{4\left(\frac{k_z}{l}\right)^2}\right]\pm\sqrt{\frac{\frac{C}{Ml}(\text{S.M.})}{(k_z/l)^2}} \quad . \quad (58)$$

Thus, the damping of the directional mode :

(1) Increases with increasing total cornering stiffness of the vehicle ;

(2) Increases with decreasing mass of the vehicle ;

(3) Decreases with increasing speed of the vehicle, and

(4) Increases with decreasing ratio of radius of gyration in yaw to vehicle wheelbase.

The frequency, on the other hand, is defined only for positive values of static margin, and

(1) Increases with increasing total cornering stiffness ;

(2) Increases with decreasing vehicle mass ;

(3) Increases with increasing static margin, and

(4) Increases with decreasing ratio of radius of gyration in yaw to vehicle wheelbase.

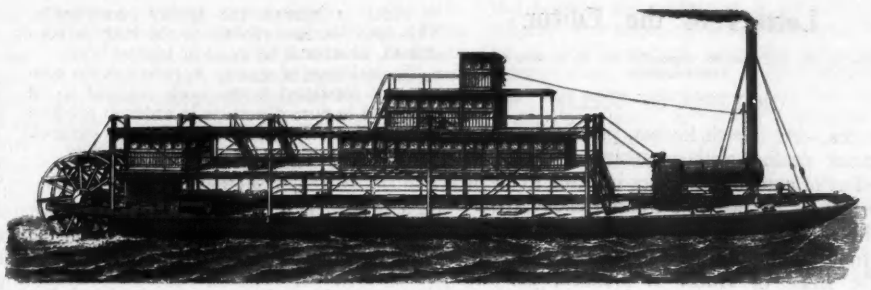
Figs. 9 and 10 show relationships between transient response and velocity for the Buick car in understeer and oversteer trim, obtained by solution of the equations of motion, these results being derived at Cornell by the use of an analogue computer.

(To be continued)

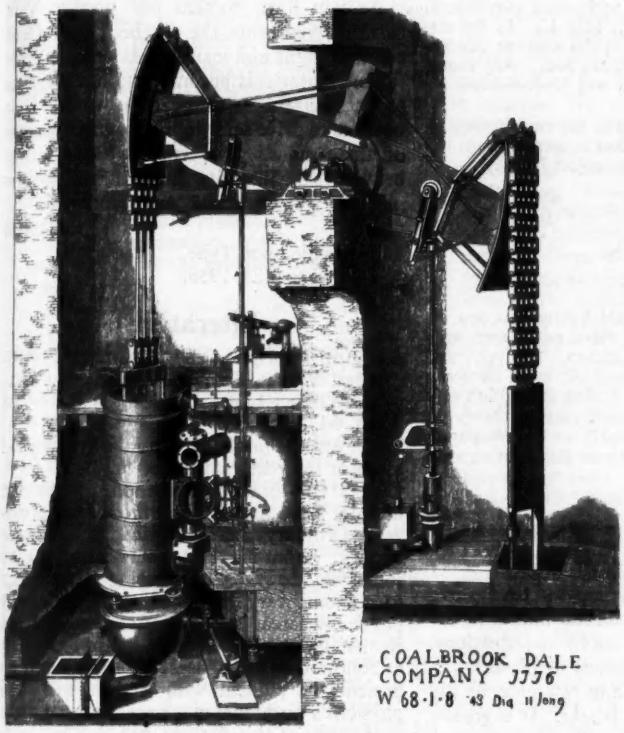
DIESEL ENGINE MOBILE TRAINING EQUIPMENTS.—Two mobile training equipments designed to give practical instruction in maintenance, fault finding, turning and to demonstrate the stripping and rebuilding of Perkins diesel engines have been built by F. Perkins, Ltd., Peterborough. With these mobile units training can be done at the premises of manufacturers, distributors and dealers overseas, and the equipments are at present in use in France and in Germany. The units are built on Dodge 3-ton, long-wheel-base chassis, powered by Perkins "P4" engines, and each includes four self-contained, removable power packs fitted in special cradles, which can be quickly unloaded and prepared for demonstration purposes.

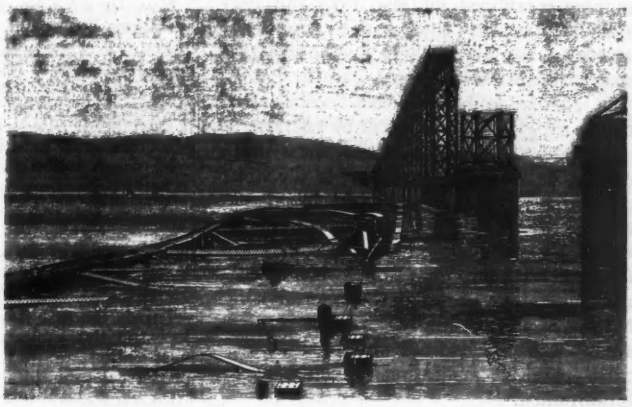
ENGRAVINGS OF 1880

The right-hand engraving, reproduced from our issue of January 16, 1880, illustrates a "stern-wheel mail steamer for South America," which was built at the Thames yard of Yarrow and Company. There were two of these steamers, their principal dimensions being 130ft length by 28ft beam. They were fitted with compound surface condensing engines, the boiler pressure being 160 lb per square inch.



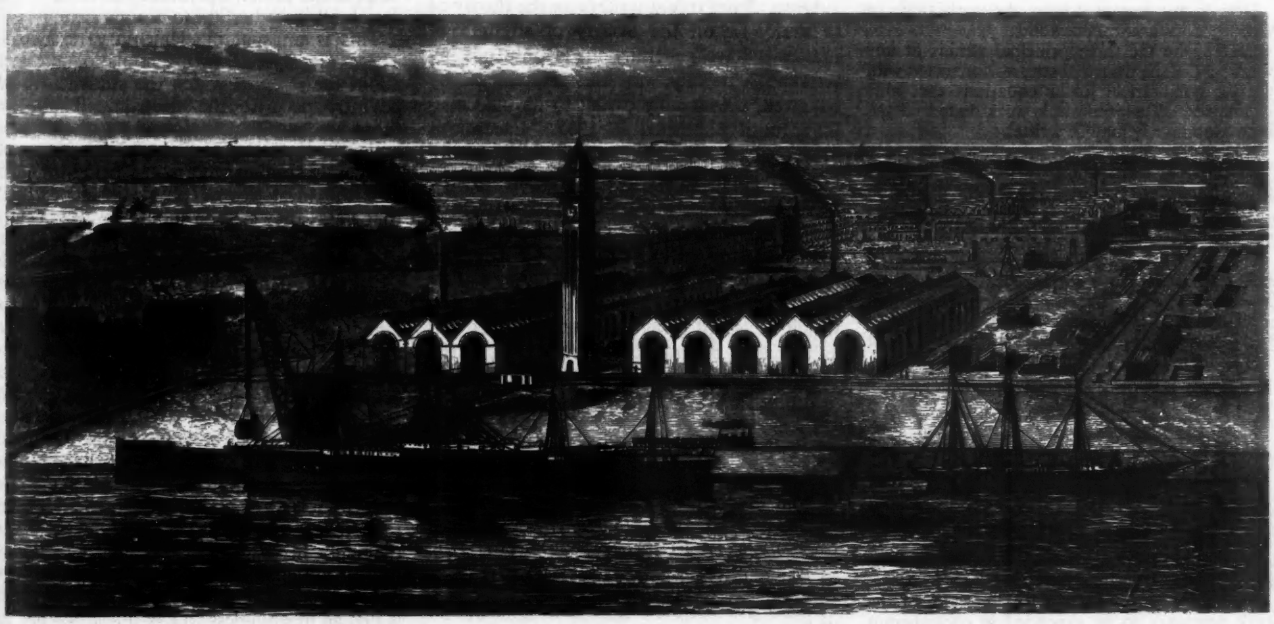
The engraving below shows an atmospheric engine at the Old Handley Wood colliery of The Stuveley Coal and Iron Company. The engraving is reproduced from our issue of January 30, 1880, wherein we pointed out that the engine was over 100 years old, but had nevertheless still been working at the end of 1879.





On the last Sunday evening of December, 1879, "shortly after seven o'clock, a large portion of the Tay Bridge fell into the stream below." In succeeding issues, we dealt in considerable detail with various aspects of this disaster. The engraving above, which is reproduced from our issue of January 30, 1880, shows the fallen girder of the bridge. Criticising the secrecy with which the inquiry into the disaster was being conducted we commented: "all the evidence goes to show that the design of the bridge was defective to such an extent that no perfection of material could make it better, while no defect in the quality of the metal could make it worse."

The Barrow Shipbuilding Company's works at Barrow-in-Furness were described in our issue of June 25, 1880, from which the engraving below has been reproduced. Our article says: "as the company started quite untrammelled with old buildings it resolved that everything should be planned on the most modern principles. The works stand on 60 acres, situated on Barrow Island."



LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

CRITERIA OF YIELD

SIR,—As is well known, practically every paper dealing with plasticity or with the effect of combined stresses involves frequent reference to the von Mises-Hencky hypothesis, the von Mises-Hencky equivalent stress, and other similar terms. Occasionally the name of Huber is prefixed, i.e. the Huber-von Mises-Hencky hypothesis. The references are to papers written by the authors mentioned, in 1904, 1913 and 1924 respectively; the comparative neglect of Huber's name is probably due to the fact that his paper was printed only in Polish. This clumsy double or triple nomenclature can be avoided to some extent by referring to the hypothesis as that of critical shear-strain energy, or distortion energy, or to the stress as octahedral stress (multiplied by a constant); there are, however, serious objections to these names, not only because they are frequently inappropriate (e.g. when plastic deformation has occurred, the criterion is no longer straightforwardly that of critical shear-strain energy), but also because they carry physical implications which may be unwarranted.

The present seems an appropriate time to point out that there is a case for attributing the hypothesis to its first enunciator (or at least to one who enunciated it nearly fifty years before Huber), namely, James Clerk Maxwell. It is exactly a hundred years ago that Maxwell wrote to William Thomson (later Lord Kelvin) a letter of which an extract follows :—

129, Union Street (Aberdeen),
18 Dec., 1856.

. . . . . .

In connection with this see your brother's papers on strained wires after the stress has been removed.

Here is my present notion about plasticity of homogeneous amorphous solids.

Let $\alpha\beta\gamma$ be the three principal strains at any point; PQR the principal stresses connected with $\alpha\beta\gamma$ by symmetrical linear equations the same for all axes. Then the whole work done by PQR in developing $\alpha\beta\gamma$ may be written

$$U=A(\alpha^2+\beta^2+\gamma^2)+B(\beta\gamma+\gamma\alpha+\alpha\beta),$$

where A and B are coefficients, the nature of which is foreign to our inquiry. Now we may put

$$U=U_1+U_2,$$

where U_1 is due to a symmetrical compression ($\alpha_1=\beta_1=\gamma_1$) and U_2 to distortion without compression ($\alpha_2+\beta_2+\gamma_2=0$) and $\alpha=\alpha_1+\alpha_2$, $\beta=\beta_1+\beta_2$, $\gamma=\gamma_1+\gamma_2$.

It follows that

$$U_1=\tfrac{1}{2}(A+B)(\alpha+\beta+\gamma)^2,$$

$$U_2=\frac{2A-B}{3}\left\{\alpha^2+\beta^2+\gamma^2-(\beta\gamma+\gamma\alpha+\alpha\beta)\right\}.$$

Now my *opinion* is, that these two parts may be considered as independent, U_1 being the work done in condensation and U_2 that done in distortion. Now I would use the old word "Resilience" to denote the work necessary to be done on a body to overcome its elastic forces.

The cubical resilience R is a measure of the work necessary to be expended in compression in order to increase the density permanently. This *must* increase rapidly as the body is condensed, whether it be wood or lead or iron.

The resilience of rigidity R_2 (which is the converse of plasticity) is the work required to be expended in pure distortion in order to produce a permanent change of form in the element. I have strong reasons for believing that when

$$\alpha^2+\beta^2+\gamma^2-\beta\gamma-\gamma\alpha-\alpha\beta$$

reaches a certain limit $=R_2$ then the element will begin to give way. If the body be tough the disfigurement will go on till this function U_2 (which truly represents the work which the element *would do* in recovering its form) has diminished to R by an alteration of the *permanent dimensions*.

Now let $a\,b\,c$ be the *very small* permanent alterations due to the fact that $U_2>R_2$ for an instant. Whenever $U_2=R_2$ the element has as much work done to it as it can bear. Any more work done to the element will be consumed in permanent alterations.

Therefore if $U_2=R_2$ and in the next instant U be increased, dU must be lost in some way.

My rough notion on this subject is that

$$a=\frac{dU}{U}\alpha,\quad b=\frac{dU}{U}\beta,\quad c=\frac{dU}{U}\gamma$$

the new values of $\alpha\beta\gamma$ will be

$$\alpha'=\alpha-a,\quad \beta'=\beta-b,\quad \gamma'=\gamma-c.$$

This is the first time that I have put pen to paper on this subject. I have never seen any investigation of the question, "Given the mechanical strain in 3 directions on an element, when will it give way?" I think this notion will bear working out into a mathematical theory of plasticity when I have time; to be compared with experiment when I know the right experiments to make.

Condition of not yielding

$$\alpha^2+\beta^2+\gamma^2-\beta\gamma-\gamma\alpha-\alpha\beta<R_2.*$$

. . . . . .

At this time Maxwell was twenty-five years of age and in his second month in the Chair of Natural Philosophy at Aberdeen. There is no further reference to plasticity in the book, nor is there any reference to the subject in the *Collected Works*. It is greatly to be regretted that Maxwell did not in fact find time in his too short life to return to the subject. Even recent writers on the theory of plasticity or on the history of strength of materials have generally made only passing reference, if any, to this statement by Maxwell, presumably owing to its inaccessibility until published in 1937. Exceptions are von Iterson† and Timoshenko.‡ It will be seen that Maxwell's statement of the hypothesis is in exactly the same form as is now generally used, with the exception that he used strains instead of stresses.

It would be a graceful tribute to the memory of a great scientist in a field with which he is not generally associated, as well as a matter of practical convenience, if the criterion and hypothesis could be referred to in future as Maxwell's.

D. G. SOPWITH
J. L. M. MORRISON

Bristol
November 27, 1956

* *Origins of Clerk Maxwell's Electric Ideas* (Letters to W. Thomson), by Sir Joseph Larmor. Cambridge University Press, 1937, pages 32–33.

† *Plasticity in Engineering*, Blackie and Son, Ltd., 1947, page 68.

‡ *History of Strength of Materials*, McGraw-Hill, 1953, pages 368–9.

HOW TO AVOID BUILDING NEW ROADS?

SIR,—The kind of experience described so amusingly by Mr. Reeves (November 16) must be shared by many other motorists. Driving in Middlesbrough for the first time recently, I saw a series of signs headed "Police Notice" along the poorly-lit road. After peering dimly and dangerously at several I made out the poster legend "Mind that Child!" A week or so later I read a report that some success had attended this campaign, in most towns, but not in Middlesbrough!

As you have pointed out previously in editorial comments, the number of plain and coloured signs and instructions designed (*sic*) for the motorist is becoming so numerous as to be dangerous. In certain places it is possible to drive safely only by ignoring some of these signs. The choice becomes one between safe illegality and dangerous compliance. Which would you recommend?

G. LYON

Newcastle upon Tyne,
November 27, 1956.

Literature

Electrical Principles. By H. COTTON. Published by the Cleaver-Hume Press, Ltd., 31, Wrights Lane, London, W.8. Price 12s. 6d.

THIS excellent textbook is primarily designed to cover the requirements of the "O" level, General Certificate of Education, and it could usefully serve also for the first and second-year Ordinary Level National Certificate courses. What makes it timely is that it goes some way towards introducing the student to contemporary ways of thinking about physics, whereas the present tendency at the elementary stage of teaching is still too much to follow the line of least resistance and to present the student with a picture of the physicist's world that may have been adequate at the turn of this century, but that is somewhat remote from current thinking. The book under review opens, for instance, with a very brief introduction to atomic structure.

This is unusual in elementary textbooks. There are indeed two schools of thought about the stage at which the student should be introduced to the electron. There are those who say that the concepts of electrons and atomic nuclei are beyond the grasp of the young student who is just being initiated into the mysteries of physical science. At that stage, they say, he should be taught only about things that he can observe, such as attractions and repulsions between pith balls, and deflection of the galvanometer needles that record the current flowing in a circuit with constant resistance when the applied voltage is being varied. Such teaching does, it is true, enable the student to acquire a collection of facts that, though apparently unrelated to each other, provide a firm foundation for later more advanced work; but the philosophy suggested by this very empirical approach is that facts are things to be learnt and remembered rather than to be understood. The student learns the facts in the same spirit that he learns those Latin words into which English ones have to be translated; to him it seems that it is just as meaningless to ask questions begin-

ning with "why" about things taught in physics, as it is to ask why the Latin word for table should be *mensa*.

According to the other school, one should let the student know as early as possible that ever since Newton gathered the facts of mechanics together into a few broad generalisations the unification of all the physical sciences under one roof has been one of the most important achievements of the modern world. According to this school the student should be helped to learn that in physics facts are not unrelated but are connected elements of a firm logical structure and that in this science questions beginning with "why" have a significant place. Adherents of the second school will welcome an elementary textbook that begins with the structure of the atom, for what is said about it helps again and again to answer questions beginning with "why." In the book under review conduction in metals and the nature of resistance are explained in terms of the movement of electrons; magnetism is explained in terms of the spin of the electron; understanding of electro-chemistry is helped by an explanation of ionisation; conduction through gases as well as thermionic emission are explained in terms of the forces between electrons and ions near the surface of a metal; the action of a dielectric does not have to appear as just one of those properties of a substance that defy explanation, but is presented as a consequence of the presence of dipoles in the material.

Adherents of the first school sometimes say that it places too great a burden on the student if he is expected at an early stage of his studies to interpret observed facts in terms of unobservable electrons, but we doubt whether it is really so. It seems instead that the burden falls more on the teacher than on the student, and it is the responsibility of the teacher to shoulder it.

The book under review differs more in treatment than in the ground covered from other textbooks at the same level. But an innovation for an elementary book is that rationalised M.K.S. units are employed. It is a welcome one, for few, if any, advanced textbooks on electrical engineering employ c.g.s. units nowadays, and the time has surely come when the student has a right to be introduced at the beginning to the units that he will have to become accustomed to in his professional work. The mystical notion that the two c.g.s. systems of units in electricity and magnetism are more scientific or more natural than the M.K.S. ones deserves to be killed. However, the author might have grasped the nettle more firmly and mentioned permittivity and permeability in the discussion on mechanical and electromagnetic units in Chapter 5. The student's path would be smoothed if it were explained to him, for instance, that Coulomb's law applies to charges in any medium when it takes the form

$$F = Q_1 Q_2 / 4\pi\epsilon r^2.$$

In such a formula one is concerned with so much permittivity just as one is concerned with so much charge and so much distance between charges. If the student is told this he is helped; but it only confuses him to make an unnecessary distinction between relative and absolute permittivity, where the latter is defined as what is measured in a vacuum. In the M.K.S. system this so-called absolute permittivity is not even unity.

We cannot but wish that the commendable practice of explaining facts had been extended to the inverse square law mentioned on page 317. Here, as elsewhere, it is presented, in conformity to time-honoured custom, as the result of experimental researches, and the student is left with the impression that the law could not have been known without the experiment. It is high time he was taught to relate this law to the law of mechanics that asserts that action and reaction are equal and opposite. This is only another way of defining a force as something that acts from one body on another. This is sometimes represented pictorially and metaphorically by saying that tubes of unit force extend between the places respectively of action and reaction. The rather artificial geometrical system for which the inverse square law holds consists of two concentric conducting spheres with an electric charge on the inner one. In such a system the tubes of force are uniformly divergent and their surface density on the outer sphere is proportional to the inverse square of the radius of that sphere. As the force is by definition proportional to the surface density of the tubes, this too must be proportional to the inverse square of the radius. In other words, the inverse square law is the logical consequence of the definitions of a force and a sphere. The law is a tautology and constitutes a statement about Euclidean geometry, not, as universally misrepresented, specifically about electricity, magnetism and gravitation. The young student knows quite enough to be able to understand this, so why persist in misleading him into the belief that there are three inverse square laws, which by some incomprehensible accident all have the same form although they are respectively concerned with electricity, magnetism and gravitation? This is not the way to introduce the student to the unity of the physical sciences. However, this is no criticism of the book under review, but a criticism of the established outlook.

To sum up, this book is exactly what is needed for the training of the rising generation, both in schools and in technical colleges.

Erection of Constructional Steelwork. By THOMAS BARRON. Iliffe and Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price 15s.

THIS volume has been published for the British Constructional Steelwork Association, its sub-title—"A Text Book for Junior Site Engineers and Students"—giving a good idea of its scope and intentions. It is a companion volume to the Association's *Constructional Steelwork Shop Practice*. The emphasis throughout is on instruction in the practical side of structural steelwork, and it covers matters which have customarily been left to the engineer to pick up haphazardly as he gains experience of this class of work. For the graduate engineer, for example, the instruction given will form a complement to the structural engineering taught at the university. There has been some emphasis in one or two recent textbooks—for example, Twort's book on the duties of the resident engineer—on giving instruction in the practical matters of site work, an emphasis which is, of course, an essential complement to an engineer's academic study.

In this case, site organisation, as applied to steel erection, is explained, and all the various tools and tackle which the steel erector needs are described. The book then goes on to a dissertation of erection methods, and has chapters on bolting and riveting, welding and flame cutting as they particularly affect site work. The organisational side of the site engineer's work is discussed in chapters on elementary surveying, estimating, costing, planning, and building regulations.

Bridging the Years. By C. M. NORRIE. Edward Arnold (Publishers), Ltd., 41, Maddox Street, London, W.1. Price 21s.

A SHORT history of British civil engineering is given in *Bridging the Years*, written mainly, it is stated, for young civil engineers. But because the profession is not often the subject of a historical study, the book will be of wider interest than for the young student alone. The work of civil engineers like Sir John Hawkshaw and Sir John Wolfe Barry is not very widely known to-day, and the account given of their achievements, if brief, still stimulates interest. It is also specially interesting to see a chapter on the personalities of the civil engineering contracting industry of Victorian and subsequent times, with illustrations of its leaders, such as John Mowlem and Charles Brand.

Our principal criticism is that the book is too short to do justice, even on the basis attempted, to such a vast subject. The reader is left wanting to know more about these fascinating characters and the problems they surmounted. The treatment is roughly chronological, up to the period 1914–18. Subsequent history is given rather sketchily and it would have been better, surely, to have carried on the tale of personalities in the contracting and consulting worlds at least up to 1939? Nevertheless, a pleasant account has been given of the growth of a powerful force in contemporary development.

Atomic Structure and the Strength of Metals. By N. F. MOTT, F.R.S. Pergamon Press, Ltd., 4 and 5, Fitzroy Square, London, W.1. Price 15s.

THE author, Cavendish Professor of Experimental Physics in the University of Cambridge, presented the Page-Barbour Lectures for 1956 at the University of Virginia last October. The three lectures form a qualitative account for the non-specialist of the phenomena of elastic and plastic yield, of alloying and work-hardening, and of low-temperature brittleness. Those engineers who have not kept pace with the emergence of the physics of metals will welcome this simple account of the nature of dislocations and their influence on crystal growth: they will have to bear in mind that "strength" herein means "yield point," so that "whiskers" of tin are the strongest material discussed. Many of the photographs are not merely immensely significant but beautiful.

Books Received

Unger Massivbrucken Teil I. By Dr.-Ing. Hans Unger. B. G. Teubner Verlagsgesellschaft, Leipzig, Germany. Price DM.26.

Oil Fuel Applications. By A. T. Henley. Crosby Lockwood and Sons, Ltd., 26, Old Brompton Road, London, S.W.7. Price 35s.

"Speedicut" Manual of Screw Threads. Firth-Brown Tools, Ltd., Speedicut Works, Carlisle Street East, Sheffield, 4. Price 25s.

A New Era of Opportunity. By Francis B. Willmott. Ripley, Preston and Co., Ltd., 360, Mosley Road, Birmingham, 12. Price 15s.

Sutcliffe's Manual of Belt Conveying. By Harold Streets. W. and R. Chambers, Ltd., 11, Thistle Street, Edinburgh, 2. Price 25s.

Cams: Design, Dynamics and Accuracy. By H. A. Rothbart. Chapman and Hall, 37, Essex Street, London, W.C.2. Price 76s.

Factors in the Development of the Oil Industry. Edited by G. Sell. Institute of Petroleum, 26, Portland Place, London, W.1. Price 40s.

Notes on Prehistoric and Early Iron in the World. By H. H. Coghlan, Curator, Pitt Rivers Museum, University of Oxford, Oxfordshire. Price 25s.

An Encyclopedia of the Iron and Steel Industry. By A. K. Osborne. The Technical Press, Ltd., 1, Justice Walk, Chelsea, London, S.W.3. Price 90s.

"Dido" Research Reactor at Harwell

Harwell's new research reactor, "Dido," uses highly enriched uranium fuel and is cooled and moderated by heavy water. It is designed to make available thermal neutron fluxes up to 10^{14} neutrons per square centimetre per second; to be capable of producing cobalt 60 of high specific activity for hospitals and industrial use in quantities up to 30,000 curies per annum; and to maintain two large-scale "loops" for research on reactor fuel systems.

AS briefly recorded in our issue of November 23, the new research reactor known as "Dido" was started up at the United Kingdom Atomic Energy Research Establishment, Harwell, on November 21, by Sir Cyril Hinshelwood, the president of the Royal Society. "Dido" which is the latest research tool to go into operation at Harwell, is a heavy-water-moderated reactor using enriched uranium fuel, giving a maximum heat output of 10MW, which makes it the most powerful reactor of its kind in western Europe.

Its uses were outlined at the opening ceremony in a speech by Sir John Cockcroft, director of research at Harwell, who explained that it would provide for research purposes a neutron intensity (of 10^{14} thermal neutrons per square centimetre per second) forty times that hitherto available at Harwell. "This," he said, "will reduce the time required to carry out tests on components of the nuclear power stations of the future from years to weeks, and this is of enormous importance to a development programme. So the reactor vessel contains many pockets in which samples of fuels for future reactors can be irradiated. It is also permeated with tubes in which we will place the 'loops' which are like working components of future power units. In one loop we will circulate hot carbon dioxide or other gases past fuel elements of different kinds to see how much we can increase operating temperatures of gas cooled reactors of the Calder Hall type. In another loop we will study the interaction of hot water with reactor fuel elements; in another a liquid fuel containing enriched uranium will be pumped around. Each of these loops is a complicated piece of equipment and the circulating fluids may be highly radioactive. So shielded rooms have to be provided round the reactor for the components of the circuit outside the reactor. Other more academically minded physicists will use the reactor to see how displacement of atoms by neutron bombardment affects the physical properties of metals. The increase of creep under irradiation discovered by Cottrell is an important example of this type of work. From other holes in the reactor shield powerful neutron beams will emerge to be used for physical research. These neutron beams will be interrupted by high-speed rotary shutters known as 'super choppers' and the pulses of neutrons will travel 100m or so along an evacuated tube. At the receiving station the interaction of the neutrons with atomic nuclei will be studied—the fastest neutron—the first arrival—will be dealt with first and finally the slowest—all arranged automatically by the electronic equipment of present day physics. From other beams, neutrons having a known speed will be separated and made to interact with crystals revealing information about the vibrational states of solids. Other neutrons will be used by neutron crystallographers to help to unravel the structure of crystals. Last but not least, all spare space round the reactor core will be packed with cobalt which will be transmuted into radio cobalt of high specific activity. With this new facility we expect to increase our annual production to over 30,000 curies per annum."

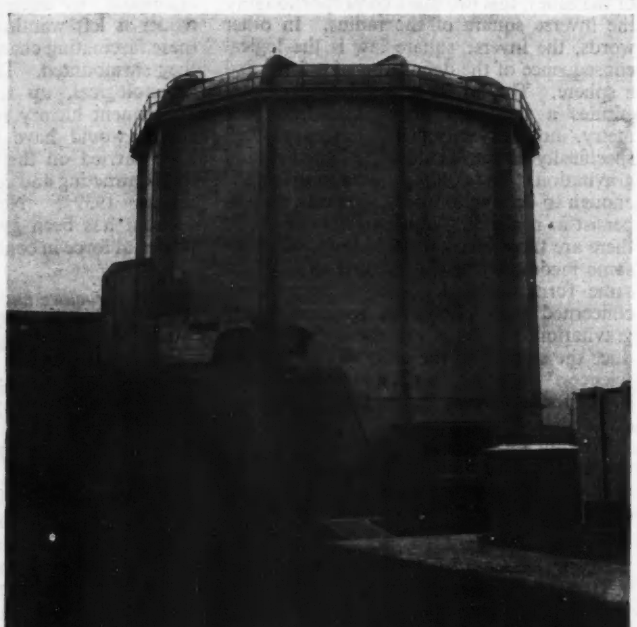


Fig. 1—Steel shell enclosing "Dido" heavy-water research reactor, showing the auxiliary plant room at ground level. Above it and to the left is the air lock enclosure with double doors

With all these uses for "Dido's" facilities it was not surprising to know, Sir John went on, that all the numerous tubes, holes and beams had long been allocated for various tasks and that a queue of "expectant users" would be waiting to use the companion reactor "Pluto" when it came into operation next year.

With "Pluto" in service the research reactors at Harwell will be as indicated in Table I, below.

"Dido" uses highly enriched uranium for fuel, and heavy water serves as both coolant and moderator. The reactor core consists of twenty-five box-like elements, each made up of ten curved plates of uranium-aluminium alloy with a thin aluminium coating, the plates being parallel and equally spaced to provide channels for the heavy water coolant. These box elements are arranged vertically in a roughly cylindrical array with a height of about 60cm and an equivalent diameter of about 86cm. In this way the core contains up to 2·5 kg of U235.

This cylindrical core is contained centrally in a cylindrical aluminium tank 2m high and 2m in diameter. The main reactor control is provided by six cadmium-sheathed semaphore arms which are pivoted to move between the fuel elements. There is also a fine control rod. The reactor core is cooled by forcing heavy water upwards between the fuel elements and between the plates of each element. The heavy water overflows above the top of the elements and is circulated outside the aluminium tank, to be cooled in a heat exchanger which uses ordinary water as a secondary coolant. The heat from the secondary coolant, in turn, is dissipated to atmosphere in forced-draught cooling towers outside the reactor building. Surrounding the sides and bottom of the aluminium tank is a graphite reflector 60cm thick. A stainless steel tank filled with helium encloses the graphite: the helium is pumped through an external circuit to remove the hydrogen and oxygen resulting from the splitting-up of the heavy water by radiation and thereby to prevent the accumulation of an explosive atmosphere in the reactor. Finally, outside the stainless steel tank there is a concrete biological shield having a 1·5m square section "window" occupied by a thermal column with appropriate external shielding, including a water-cooled lead wall.

A space vertically below the reactor and the biological shield houses the main helium and heavy water equipment, including the primary heavy-water coolers. The reactor contains about 10 tons of heavy water and to remove the 10MW of heat generated in the fuel elements (and 1MW of heat in the experimental facilities) the heavy water is circulated through the heat exchangers to give a complete change every three minutes. Because of the high cost of the heavy water (of the order of £20,000 per ton) it is stipulated that the leakage from the system should not exceed 5 c.c. per day. A strict control is therefore kept over leakage and every joint in the pipework is monitored by a leak detector. Some of these leak detectors can be seen in Fig. 4, which gives a general view of the heavy-water stainless steel pipework and valves.

The heavy-water circuits include three primary coolers with three main circulators and two emergency shut-down pumps. In the secondary coolant circuits the ordinary water is handled by four main circulators, two emergency shut-

TABLE I—*Main Particulars of Harwell Reactors, November*, 1956

Name of reactor	Date of start-up	Peak neutron flux	Maximum heat output	Moderator	Coolant	Fuel	Purpose
GLEEP ...	1947	10^{10} thermal n/cm²/sec	100kW	Graphite	Air	Natural uranium metal and oxide	Initially isotope production and general neutron physics. Now routine graphite uranium quality testing, research with oscillator, biological irradiations
BEPO	1948	$1·5\times10^{12}$	6MW	Graphite	Air	Natural uranium metal	Isotope production and general radiation source
ZEPHYR ...	1954	8×10^{12} (fast)	A few watts	None	None	Plutonium	Fast reactor studies
DIMPLE ...	1954	10^{9}	100W	Heavy water	None	Varies	Thermal reactor studies
ZEUS	1955	5×10^{9} (fast)	100W	None	None	Uranium 235	To study a particular core design for Dounreay fast reactor
ZETR	1955	4×10^{6}	Negligible	Heavy or light water	None	Uranium 233, 235 or Plutonium	To study physics of homogeneous aqueous systems
LIDO	1956	10^{12}	100kW	Natural water	Natural water	Uranium 235	Thermal reactor studies. Including shielding
DIDO ...	1956	10^{14}	10MW	Heavy water	Heavy water	Uranium 235	Isotope production, neutron physics, radiation chemistry, nuclear reactor material studies
PLUTO* ...	1957	10^{14}	10MW	Heavy water	Heavy water	Uranium 235	Nuclear reactor material studies

* A second PLUTO type reactor is also due to start up at Dounreay in 1957.

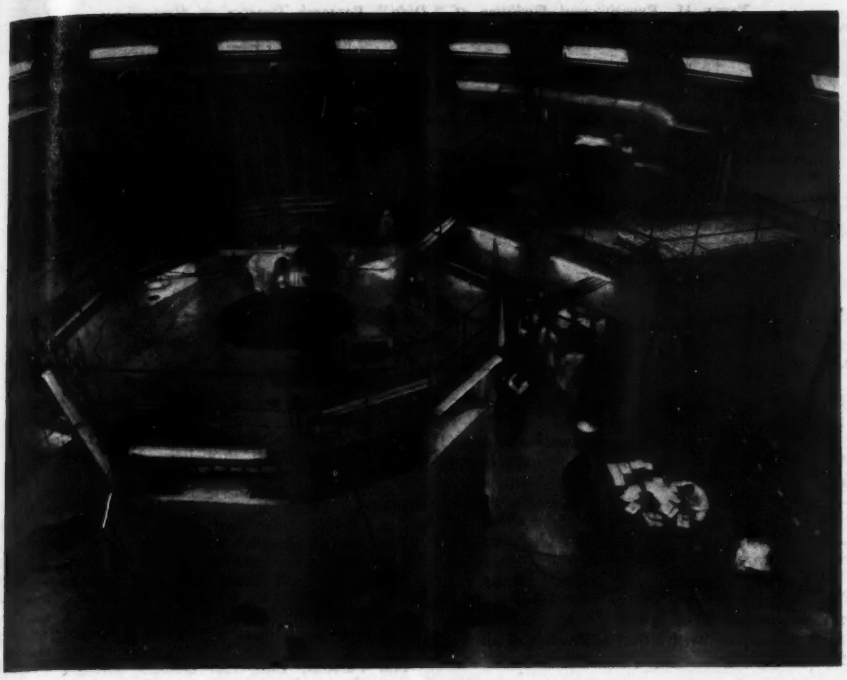


Fig. 2—"Dido" reactor during criticality experiments. Some of the experimental holes in the octagonal face can be seen. The reactor control room is on the right

down pumps and eight forced-draught cooling towers.

For shield cooling there are two water-circulating pumps, a shield water cooler and a header tank. Two pumps are also installed for supplying cooling water to the fine control rod.

The plant for handling the helium gas includes a storage vessel interconnected with a tank gasholder, an expansion vessel and a partial dump tank, with a transfer pump, two liquid level pumps and an exchange unit.

These circuits are depicted on a mimic diagram, part of which can be seen in Fig. 5, which shows the reactor control desk and panel. On the panel in front of the operator and below the mimic diagram are instruments showing ordinary-water coolant flow and temperature and heavy-water flow. The "scram" control and indicator is centrally placed at eye level. Below it is a small central panel with magslip indications of the positions of the fine control rod and coarse control arm. Indication is also given of linear power, reactor power and reactor power error.

To contain any radioactive fission products that might be released in the unlikely event of a reactor fault the reactor is completely enclosed in a welded steel shell (Fig. 1). Personnel can enter or leave the reactor area through an air lock in the shell, consisting of double doors interlocked so that they cannot both be opened at the same time. A glazed corridor can be seen in Fig. 1, connecting the double doors with the first floor of the adjoining building, which houses auxiliary plant, offices, and handling facilities. Larger double doors with airlocks are provided in the reactor shell at ground floor level, for heavy equipment and materials. The whole of the shell is lined internally with a 2in thickness of resin-bonded glass fibre. An elaborate air-conditioning system is installed. The ducting carrying exhaust air from the reactor shell can be seen in Fig. 1; this exhaust could be sealed to limit the spread of radioactivity in the eventuality referred to above.

Artificial lighting is provided by a row of fluorescent lamp fittings installed (at a height of about 20ft above the working platform) on the wall of the reactor shell, which is circular in plan. A 20-ton crane travels along a gantry spanning, diametrically, a circular track at a height of about 30ft above the working platform. With the traversing movement along the gantry and the movement of the gantry along the circular track, the crane can serve the whole reactor area. In particular it can be used to handle the 15-ton shielded flask, which serves for loading and unloading the reactor as indicated in Fig. 3.

Because of the need for containment, to which we have referred, the working space inside the reactor shell is very limited (Figs. 2 and 3), and additional facilities are being provided in adjoining buildings.

Material irradiated in the reactor will be examined in a building (now under construction), 106ft long by 33ft wide. This building will be equipped with a 20-ton overhead travelling crane, changing-room facilities and comprehensive services for power, lighting and ventilation, and for the disposal of active effluents. A deep pond will be built below floor level to allow for underwater examinations and for the dismantling of activated equipment. Remote-controlled power heads will be installed in shielded rooms to provide for the dismantling of both active and contaminated equipment, preparatory to detailed examination.

The experimental facilities built into "Dido" have been described elsewhere.* Briefly, the reactor was designed to achieve three main objectives within a total cost of £2,000,000, including heavy water, site development and the adjoining laboratories and offices: (i) to make available thermal neutron fluxes up to 10^{14} neutrons per square centimetre per second; (ii) to be capable of producing the equivalent of 30,000 curies per annum of Cobalt 60 at high specific activity, and (iii) to be capable of maintaining a limited number of loops for testing fuel system for more advanced reactor designs.

As explained in the paper by Grout and Fenning* experience with BEPO at Harwell indicated the need for three general classes of experimental facility: beams of neutron, irradiations without close control, and irradiations with close control.

Beams of Neutrons.—These beams require some collimation in the shield, a means of cutting off the beam without shutting down the pile and space adjoining the reactor face. Examples of this kind of requirement envisaged for "Dido" are a high-speed chopper-type monochromator used in conjunction with a 50m flight path and a crystal spectrometer. The holes intended for such purposes are horizontal, the shield holes opening out to large diameter half-way through the biological shield, thereby giving space in which to fit a collimator fitted with a suitable shutter.

Irradiations Without Close Control.—These requirements are the simplest to fulfil. Included in this category is the preparation of radio-isotopes where the parent material is stable in the temperature and radiation conditions available. For this purpose small diameter vertical holes and some horizontal holes are available. Their design is simple, providing only for small heat production in the irradiated specimen. This heat is removed by the reactor cooling circuits without special provision. No permanent allocation of space in the reactor building is required, but a shielded container is required for periodic discharge of irradiated material.

Irradiations in Which Close Control of Environment is Required.—These are by far the most difficult facilities to supply and operate. They include the use of holes for solid state studies, radiation chemistry studies and experimental fuel element testing. They usually require control of temperature or neutron spectrum thereby necessitating special heat removal circuits or furnaces and considerable space adjacent to the reactor for control and recording instruments. Usually the reliability of such experimental work must be as good as the reliability of the reactor itself. Clearly the maximum possible space inside the reactor and easiest access from outside the shield are desirable. In attempting to achieve these in

Fig. 3—Machine for loading and unloading being positioned above charging face of the reactor

* "The Experimental Facilities of E.443," by H. J. Grout and F. W. Fenning. International Conference on the Peaseful Uses of Atomic Energy, Geneva, 1955.

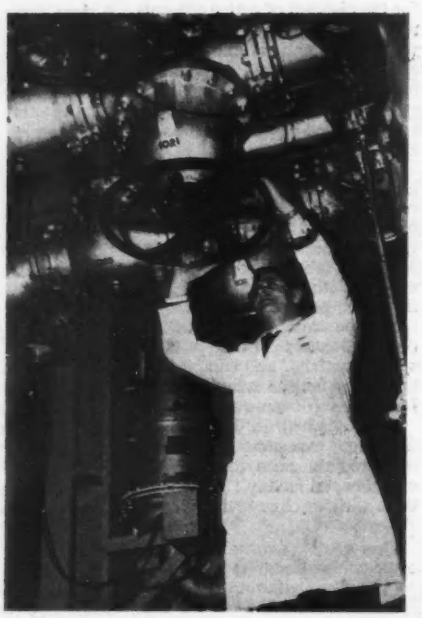


Fig. 4—Heavy-water mains and valves below the reactor chamber of "Dido." Every pipe joint is fitted with a leak detector, as can be seen here

"Dido" as many large diameter vertical holes as possible have been planned and have been made removable. Limitations referred to later have restricted the number of holes accessible to both ends and these are horizontal. Provision is made for up to 1MW of heat to be disposable from all these facilities.

Table II, herewith, indicates all the facilities which can be made available, though not necessarily all at once. Included in the table are estimates of the reactivity loss associated with the installation of particular holes, but of course the inclusion of equipment in those holes may add to or subtract from this. The flux figure quoted is the maximum thermal flux likely to be available in the facility before any equipment is installed in it.

TABLE II—*Experimental Facilities of "Dido" Research Reactor at Harwell.*

Experimental facility	Dimensions	No.	Reactivity loss due to empty facility, per cent	Maximum thermal flux in empty facility n/cm²/sec.
	diam.			
Fixed horizontal round tubes :				
(*a*) entering D_2O reflector	10in	1	0·5	8×10^{13}
	6in	1	0·2	8×10^{13}
	4in	6	0·6	7×10^{13}
(*b*) entering graphite reflector only	6in	10	—	$1·5\times10^{13}$
Fixed, horizontal oval tube passing right through D_2O reflector	4in by 2in	1	0·4	8×10^{13}
Removable, vertical round tubes :				
(*a*) entering D_2O reflector	6in	4	0·8	8×10^{13}
	4in	5	1·2	5×10^{13}
	2in	9	0·5	9×10^{13}
(*b*) entering graphite reflector only	6in	6	—	$0·4\times10^{13}$
	4in	2	—	$0·4\times10^{13}$
	10in	2	—	$0·4\times10^{13}$
Fixed horizontal rectangular tube passing right through bottom graphite reflector	8in by 12in	2	—	1×10^{13}
Thermal column of graphite containing square holes	5ft by 5ft	1	—	10^{12}
	4in by 4in	9	—	10^{12}

All holes may be purged and sealed with CO_2 to reduce ^{41}A activity in handling experimental equipment in and out during shut-down.

The reactor and its associated plant and buildings was designed and constructed by the U.K. Atomic Energy Research Establishment, in association with the Ministry of Works and Head Wrightson Processes, Ltd. The Ministry of Works was responsible for the detailed design and co-ordination of the civil works and services in association with the following industrial firms :

W. E. Chivers, Ltd., civil works ; Matthew Hall, Ltd., mechanical plant ; Whessoe, Ltd., airtight building ; J. Stone and Co. (Charlton), Ltd., air lock doors ; Andrew Machine Company, Ltd., ventilation ; Messrs Reed and Partner, electrical installation ; Brush Electrical Engineering Company, Ltd., electrical continuity sets; Wharton Crane and Hoist Company, Ltd., 20-ton circular motion crane.

Head Wrightson Processes, Ltd., was responsible for the detailed design and construction of the reactor itself and the following firms were sub-contractors for the larger equipment supplied :

Head Wrightson Processes, Ltd., cooling tower ; Head Wrightson, Ltd., erection, cooling plant ; shields ; Grazebrook, Ltd., thermal column frame and door, reactor stool, reactor steel tank ; Aluminium Plant and Vessel Company, Ltd., reactor vessel, stainless steel, heads for fuel element and experimental facilities ; H. M. Hobson, Ltd., control mechanism ; Hayward Tyler and Co., Ltd., main circulating pumps ; Hydraulic and Mechanical Developments, Ltd., auxiliary pumps ; Robert Jenkins, Ltd., heavy water vessels, shielded handling flasks for active equipment ; Metal Propellers, Ltd., heavy water vessels ; Ashmore, Benson Pease and Co., Ltd., gasholders ; W. J. Fraser and Co., Ltd., stainless clad mild steel expansion vessel; British Oxygen Company, Ltd., helium drier and absorber ; Messrs Baker Platinum, helium recombination unit ; Permutit Company, Ltd., cooling water treatment plant ; Thomas Firth and John Brown, Ltd., reactor top plate; Motherwell Foundry, Ltd., shielded doors and frames, with drives; Wright Anderson and Co., Ltd., reactor structure ; London Aluminium Company, Ltd., aluminium experimental facility thimbles ; Savage and Parsons, Ltd., fuel element shielded plugs ; Lang Bridge, Ltd., shield plugs and heads for experimental facilities ; B.K.L. Alloys, Ltd., John Thompson, Ltd., and Samuel Osborn and Co., Ltd., fabrication of stainless steel piping and fittings ; Foxoro-Yoxall, Ltd., George Kent, Ltd., Honeywell-Brown, Ltd., Evershed and Vignoles, Ltd., instruments ; Hutcheon and Duthie, Ltd., instrument panels and instrument installations.

Fig. 5—Control desk and panel for "Dido" reactor

Mobile Crane Developments

THE large mobile cranes made by Steeles Engineering Products, Ltd., of Sunderland, can now be supplied with self erecting jibs and removable tail ballast weights. Cranes with self-erecting jibs have a somewhat different derrick arrangement from those with standard bolted flange joint ribs, in that a gantry mast is incorporated for raising the equalising sheaves in the derrick reeving system. A special tubular link is supplied with the gantry mast for attachment to the mast and to the lower section of the jib for positioning jib sections prior to their erection.

If it is desired to remove a jib extension piece the joint nearest to the jib foot is dismantled first, with the remainder of the jib supported. The pins are then removed from the second joint to leave the extension section free for removal. With a short sling attached to one of the jib joint eyes, the extension section can be moved clear, using the crane derricking motion. If it is desired to increase the jib length, the additional section is positioned in line with the remainder of the jib and the reverse procedure to dismantling is adopted—the upper pins being fitted first and the jib raised by means of the derrick system until the lower joints are mated.

A means for the easy removal of the tail ballast weight on mobile cranes has been introduced to enable the vehicles to comply with road regulations in connection with permissible maximum axle loads. These tail ballast weights are bolted to the underside of the superstructure base and to revolve its weight the crane superstructure is slewed over the rear position. Two power jacks fitted on the crane chassis are extended to take the weight of the ballast as it is unbolted and on them the ballast is lowered clear of the superstructure.

In the case of cranes fitted with 30ft jibs the superstructure can be slewed to the forward position and the lowered ballast weight lifted clear of the crane. With cranes having longer jibs the ballast is lifted clear by using the crane hook on to which is looped a suitable sling reeved through a guiding sheave specially arranged for this purpose on the underside of the lower section of the jib.

Machinery at the Smithfield Show

No. II—(*Concluded from page* 783, *November* 30)

THE Smithfield Show and Agricultural Machinery Exhibition opened at Earls Court, London, last Monday morning, and will close this (Friday) evening. It is the only indoor exhibition of its kind in this country, and is, in fact, the only comprehensive agricultural show that is held annually in London. That alone, we believe, attracts a large number of visitors from the metropolitan area, as well as many others who are concerned in some way or another with agriculture in this country and overseas. Agriculture in this country continues to be an enormous industry, yet it produces barely half the food requirements of the population. But, according to Sir James Turner, the president of the National Farmers' Union, the output value of British agriculture is about £1400 million a year.

The achievement represented by a figure of that order is made possible by the high degree of mechanisation on the land. At the Smithfield Show, there are examples of just about all the machinery and implements which the engineering industry provides to assist farmers at home and abroad to get the best out of the land. In our last issue, we began a general survey of the machinery at Earls Court by making brief reference to some recent tractor developments. Here we deal with a few of the many machines and other equipment displayed.

Harvesting Machinery

The difficulties caused by the bad weather which prevailed throughout this year's corn harvest were largely overcome in this country by the efficient work of combine-harvesters. The number of these machines operated in this country continues to increase, and at least two new models are to be seen at the Smithfield Show, in addition to those which have been available for some years past. The first of the new combines (Fig. 3) is one which is being developed by Ransomes, Sims and Jefferies, Ltd., Ipswich. It is a self-propelled machine, powered by a Ford diesel engine which gives 57 b.h.p. at a governed speed of 2150 r.p.m. The machine has a cutting width of 12ft and, as the crop is thrown on to the "table," it is taken by a chain and slat elevator to a 39in threshing drum, which is fitted with eight beater bars. There is an open-grate adjustable concave, and four shakers which, with double sieves, complete the actual threshing equipment. Another chain and slat elevator takes the tailings and delivers them either to the drum or the shakers and the grain is taken by a roller chain and bucket conveyor to the grain tank on top of the machine. This tank has a capacity of 50 bushels, and, it is stated, can be emptied through its discharge auger in two minutes. The combine has been designed so that the table, or platform, on to which the cut crop first falls, is lifted smoothly by the action of a hydraulic ram. The arrangement is such that when the table lifts to pass over an obstruction, it automatically returns to its former cutting height. There are three forward travelling speeds between 0·5 and 11 m.p.h., and the claim made for the harvester is that it can deliver up to 6 tons of grain an hour.

A smaller combine-harvester, which makes its first appearance at the exhibition is a tractor-mounted machine produced by Massey-Harris-Ferguson, Ltd., Coventry. This harvester has been designed to meet the needs of farms which have a limited grain acreage; its cutting width is 7ft 6in, and it is shown mounted on a Ferguson "35" tractor (which was described in THE ENGINEER, October 5, 1956). The machine is, of course, driven by the power take-off shaft of the tractor. The threshing equipment includes three beaters which are arranged so that the peripheral speed of each is greater than that of the preceding one. Another item of the equipment is a "rethresher" which replaces the more normal gleanings auger and elevator. The gleanings are collected and fed to an auger from which they pass to a small peg drum carried on the same shaft. From this drum, the rethreshed material is conveyed, by the action of a fan, to the grain pan. By the use of the tractor's hydraulic lift, the height of cut can be varied with this combine between 2in and 32in. The table is protected by steel skids and in its "dropped" position a compression spring assists it to ride over ground undulations without the need for constant height adjustment.

Equipment for harvesting includes the pick-up baler, the use of which has increased considerably in the last decade. The various machines of this kind which are now available have been developed from stationary hand-operated baling presses which were produced in this country more than forty years ago. The balers which are now made are tractor-drawn machines, and in some cases their moving parts are operated by a tractor power take-off shaft; in others a separate engine mounted on the machine itself provides the power for the baling operation. The principal parts of all pick-up balers are a plunger which pushes the loose hay or straw through the mouth of the receiving hopper into the rectangular baling chamber; a ram running on rollers within the chamber, a bale slicer and a knotting mechanism which binds the completed bale. The baler illustrated in Fig. 4 is one which is exhibited by International Harvester Company of Great Britain, Ltd., 259, City Road, London, E.C.1. It can turn out 15in by 19in bales, variable in length between 36in and 40in, and weighing from 80 lb to 125 lb. This machine is driven by a 22 b.h.p. Armstrong Siddeley diesel engine. In this baler the slicing of the material is done, as it enters the baling chamber, by a knife mounted on the plunger. The bales are tied with twine by twin knotters. Before that part of the operation, however, as each bale is formed, a metering wheel on the side of the baling chamber turns with the advancing bale and measures its length. This metering wheel is coupled to a trip finger by two bevel gears, and as the bale reaches the preselected length, the trip finger engages a release mechanism, thus permitting the needles and knotters to function.

Fig. 4—Tractor-hauled hay and straw baler. The machine is operated by a 22 b.h.p. diesel engine

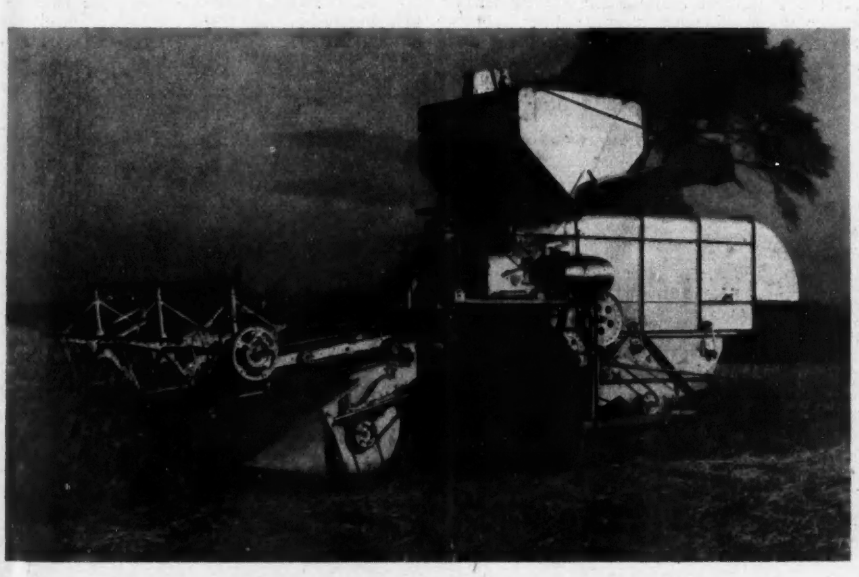


Fig. 3—Self-propelled combine-harvester with 12ft cutting width. It is powered by a 57 b.h.p. diesel engine

Ditch Cleaning and Trenching Machines

Machines for ditch cleaning and for trench digging for field drainage are well represented at the Smithfield Show this year. A big farming problem is the carrying out of regular maintenance work on hedgeside ditches. The land drainage division of the Ministry of Agriculture has estimated that, in England and Wales, there are approximately 186,000 miles of open ditch.

Fig. 5—Crawler mounted dragline ditch cleaner

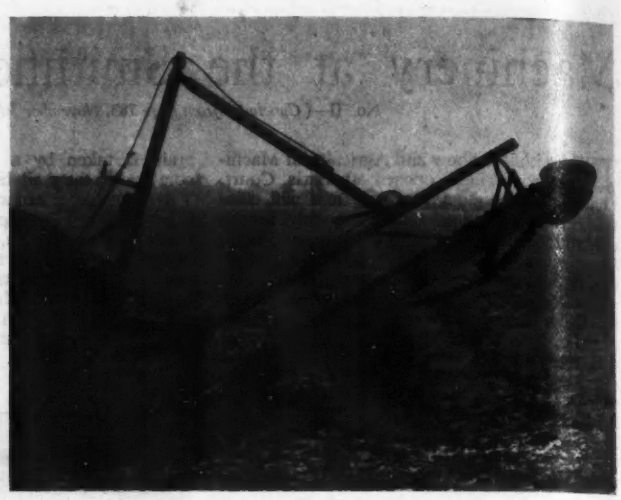


Fig. 6—Trench cutting machine for drain laying

Of that total, roughly 13,000 miles are "self-cleansing" and require little or no attention, but it means that 173,000 miles of ditches do need regular maintenance to prevent them from silting up. The need for encouraging fuller mechanisation of this kind of work is well realised, and the Royal Agricultural Society is holding a competition for ditch cleaning machinery.

Some of the machines which are entered for that competition are shown at Earls Court. One of them is a dragline ditch cleaner (Fig. 5), operated by a "County" crawler tractor, and built by Whitlock Bros., Ltd., Great Yeldham, Essex. The ditch cleaning attachment consists of a double drum winch, driven from the tractor's power take-off through reduction gearing, each winch being controlled by friction clutch and brake assemblies operated from the tractor seat. A steel cable passes from the winch, through a snatch block on a frame at the back of the tractor, to the end of an adjustable arm offset and projecting from the front of the tractor. This arm can be raised and lowered through ball joints according to the depth of the ditch to be cleaned. A large bucket, fitted with an automatic ejector plate, is swung and lowered over the ditch by a second steel rope. The bucket is then drawn along the bottom of the ditch and up to the arm by the first rope, before being lifted out and dumped well to the back of the tractor, and away from the ditch, by the second rope. The tractor, of course, travels alongside the ditch in forward gear, enabling the bucket to be completely filled before it is lifted out. The same machine, incidentally, can be used for dredging dykes, it being possible to attach dredger blades from 6ft to 10ft long. In addition, the ditch cleaner boom, when the bucket is removed, can be used as an offset crane capable of handling loads up to 15 cwt.

A simply-constructed machine for trench digging preparatory to drain pipe laying (Fig. 6) is shown by William Reynolds and Sons (Bedford), Ltd., 85, Newnham Avenue, Bedford. This machine, which can be attached to the three-point linkage of a wheeled tractor, consists of an adjustable arm, carrying a boom around which a chain elevator revolves. The digger is raised and lowered by the tractor's hydraulic lift and makes a cut 4in deep, the excavated earth being raised by the chain elevator and deposited well away from the trench. The elevator is driven either by the toothed land wheel of the machine or by the tractor's power take-off shaft. The maker states that a trench up to about 40in deep and 8in wide can be cut and graded for pipe laying with the machine. A complementary piece of equipment which is shown by the same firm is a pipe layer for laying 3in and 4in agricultural drain pipes. It is simply a semi-circular metal chute which can be attached to the back of a farm trailer. The pipes slide down this chute into the prepared trench; the bottom of the chute being so shaped that it brushes away any loose earth.

Tillage Implements

The classification "tillage implements" now quite properly incorporates a big array of tools and machines which are used regularly for moving the soil and for other aids to cultivation. At the Smithfield Show there are numerous examples of ploughs, steerage hoes, rotary tillers, disc harrows, manure distributors and seed drills. With many of these implements, a good deal of time can frequently be occupied in transport from one field to another. This problem has to a large extent been overcome by the use of the tractor power lift, but that does not always provide the answer. In some disc harrows (Fig. 7) which have been produced by E. H. Bentall and Co., Ltd., Maldon, Essex, careful attention has been given to the design of the transport wheels. The implement illustrated is 7ft wide with two banks of 28in by 18in discs. The transport wheels are secured by lynch pins with a spring ring, and can be quickly swung over to rest on the top of the frame when the implement is in work. Although the main frame of the harrows is rigid, the disc sections are flexible to enable the contours of the land to be followed, thus assisting an even tilth throughout.

The "implement" illustrated by Fig. 8 can quite properly be included in the tillage group, for it is described as a "multi-purpose machine." It is the "Almak" which is of German manufacture, and which is distributed in this country by Mitchell, Colman and Co., Ltd., Radcliffe, Manchester. The machine can be used for a diversity of jobs including tedding and swath turning, manure spreading (as shown in our illustration), potato haulm disposal and kale cutting. The "Almak" consists essentially of a revolving disc on which rings are fitted according to the work to be done. These rings are fitted with tines, a ring with single tines being used for such tasks as haymaking, and double tines being fitted for manure spreading. For operations like potato haulm disposal and kale cutting, swinging beaters are fitted on the ring in place of the tines. The "Almak" can be mounted on

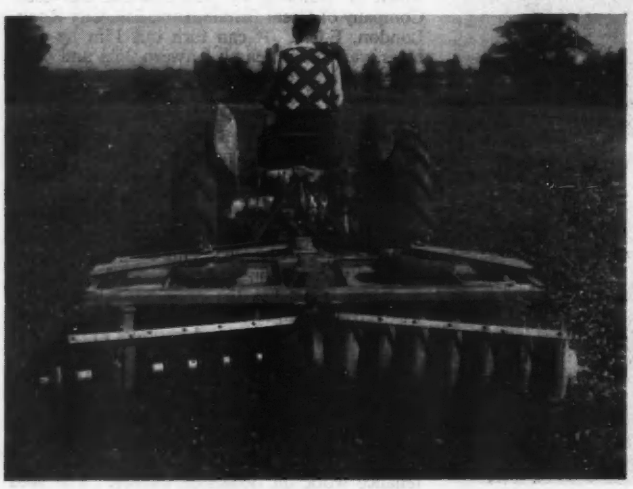


Fig. 7—Disc harrows; the transport wheels can be swung over to rest on top of the frame when the implement is in work

Fig. 8—A "multi-purpose" machine. Here it is shown manure spreading

Fig. 9—One-ton capacity general-purpose truck

the three-point linkage of a tractor or it can be towed and driven from the power take-off. The width of the machine is 6ft 3in, and its weight no more than 420 lb.

Some Other Equipment

In addition to the various categories of machines and implements mentioned in this general survey of the Smithfield Show, there are, of course, many other items in the machinery section which have an increasingly important place in mechanised agriculture. The transport and handling of materials on farms and in many other establishments also, take up much time and labour. Our last illustration (Fig. 9) shows an exhibit that has been designed to assist in this direction. It is a 1-ton truck built by Frank Bonser and Co., Ltd., Hucknall, Nottingham. The truck has two rear driving wheels and is steered by a single front wheel. A 5 h.p. to 6 h.p., four-stroke petrol engine provides the power, and the gearbox is arranged to provide for three forward and one reverse speeds, the top speed being 12 m.p.h. The equipment includes Girling mechanical brakes and geared steering, and the hand tipping body is 5ft 6in long by 4ft wide by 1ft deep.

Finally, there are some noteworthy items of electrical equipment. As but one example of the importance of electricity in agriculture, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, is demonstrating the equipment it provides for grain and grass drying. In the G.E.C. exhibit there is special emphasis on equipment for smaller farms; they were, in many places, hard hit by this year's wet harvest. One model shown on the G.E.C. stand is a tray drier for grain, which can be quickly assembled. This equipment includes a steel tray of 50 cubic feet capacity which has a perforated metal floor. The floor of the tray is inclined to assist loading and unloading, and there are two discharge outlets with sliding valves for bagging the grain or emptying it on to a conveyor or into a pit. The drying apparatus consists of a 0·7 b.h.p. Woods "Aerofoil" fan and a 22kW G.E.C. duct air heater, with thermal protection and guard. There are steel transformation pieces with gaskets and bend for attaching the drying unit to the air plenum chamber, the chamber itself being located under the tray. This drier, incidentally, is delivered in sections which are convenient for handling and for carrying through doorways and into lofts. In operation, the drier, it is stated, gives an extraction rate of approximately 1 per cent per hour.

Mechanised Motor Body Building

Sheet steel panels and assemblies for automobile bodies are difficult and costly to store in between operations. In this article some of the techniques of flow production at Briggs Motor Bodies, Ltd., are described.

A MAJOR problem in the production of automobile bodies is the great bulk of the finished product and of the sub-assemblies which renders it uneconomic to install exceedingly productive automatic machinery whose output is many times the desired production rate. An allied difficulty is that cars are exported in the knocked down (K.D.) condition, so that a proportion of the sub-assemblies do not require to be built up and must nestle compactly together. In equipping the Dagenham, Essex, works of Briggs Motor Bodies, Ltd., to build the body shells for the Mark II Ford cars introduced this year, several interesting techniques have been employed to relate the speed of individual operations to the required output—at present 500 cars per day.

In the press shop the principal innovation has been the introduction of mechanised transfer equipment, which not only decreases cycle times but also reduces operator fatigue; associated benefits are greater safety and the elimination of stacks of work beside machines. The equipment comprises loaders, extractors, turnover devices, and conveyors. The loaders drive panels into position in the presses, being themselves loaded by hand, and a typical loader has a stroke of 52½in and a cycle time of two and a half seconds. They are driven by electric motors through electric clutch brakes, and linear motion is developed by sprocket chains. Similar mechanisms equipped with extractor jaws are used as extractors with strokes up to 84in. Smaller extractors are driven by pneumatic rams, the stroke of the ram being halved by use either of chain and sprocket devices again or of levers. The rams are specially developed to incorporate a cushioning effect at the completion of each end of the stroke, without any added complication in the valve gear. The extractor jaws are given a short jerk action by another pneumatic cylinder; the largest extractors are provided with two jaws to ensure that the panel remains square to the direction of motion.

The loaders and extractors are actuated from the press by electric contacts operated by cams on the crankshaft; the action of each cam can be timed to within 0·1 second. A further development is a commutator of 180 segments swept by a bush arm rotating with the press which will energise relays at any desired point in the cycle to the nearest degree. The press cycle is started by each attendant laying both hands on palm buttons; in many cases, guards linked to the ram sweep clear the danger zones.

Turnover devices may be included in extractors or be independent; in essence they consist of a row of rollers, on to which the panel is pushed, mounted on an arm that can be raised past the vertical. The panel then falls on to the fabric belt of a conveyor. The conveyors all run at 50ft per minute and vary from 12ft to 24ft long; several can be joined to link operations together. Automatic stops can be installed to cut the motor when a panel reaches the end of the belt. Fig. 1 shows outer door panels on a pair of conveyors, while in the background a third panel is being extracted from the flanging press; it can be seen that the extractor jaw hooks under the panel to avoid marking its surface.

Welding Techniques

A variety of methods of welding are used, and a component that demonstrates a number of them is the front fender or wing. As can be confirmed from our illustration of a completed car on May 4 last, page 448, the designer has placed the headlights high up and far apart in order to allow the driver to judge the extent of the car (the same requirement, interestingly, has been applied at the rear), and therefore the fender is sharply rounded and too deep to be drawn from sheet. The preforming of the panel amounts to wrapping the metal into a truncated skew cone, the truncation corresponding to the headlight mounting, and the resulting lap joint is automatically spot welded. The panel is then pressed to the final shape, with the seam running from the lamp location to the air intake. The first assembly operation is for the rear edge to be folded over a reinforcement, a curved angle seen in section in Fig. 2; at the same time, some spot welds are made by hand. When the clinched flange is to be welded to the reinforcement, it is important to minimise the deformation of the outer surface of the fender, since this subsequently has to take a high finish. The electrodes are therefore arranged as in Fig. 2, using steel electrodes at the bottom. It can be seen that the closer together the electrode pairs are, the more important the interfacial resistances become, and the greater the proportion of current carried by the upper layers of material. Since the reinforcement is of heavier gauge than the skin, a heavy weld current through the reinforcement can be obtained with very little heating of the outer surface. These series welds are done on separate machines for left and right-hand components, wired so that only one can be in action at a time.

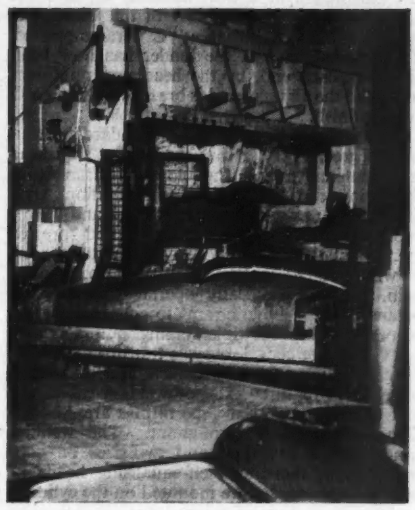


Fig. 1—Transfer equipment handling pressed outer door panels

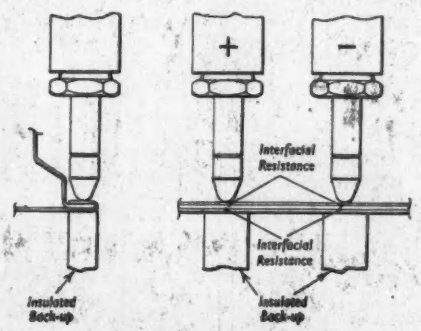


Fig. 2—Series welding of clinched flange to reinforcement

The next addition is the headlamp mounting; owing to the limited range of adjustment on lights such as these, accuracy is of prime importance. The fenders, either left or right, are located on a pneumatically operated machine, and a

series of spot welds made around the lamp mounting. To keep the low-tension cables short, all live electrodes are in front of the fender, and series welding is employed again. Two equal thicknesses of metal are to be joined, and a copper back-up block is used ; there is here a minimum electrode pitch at which the shunt through the upper layer of metal becomes unacceptable.

The principal problem in the next operation, the attachment of a duct directing air into the radiator, is the inaccessibility of the joint ; the weld is carried out in large "C" frame presses. The original joint in the fender has now been closed at each end, by the headlamp reinforcement and the air duct, and is brazed to give a good surface finish.

All the welding equipment is standardised to a high degree, in order that the highest skill level of maintenance and the closest tolerances at inspection can be achieved—in addition, time and money are saved on tool design and spares provision. Besides the open-fronted presses mentioned, there are only two other patterns, one of which comes in three strokes, 12in, 18in or 24in, and is hydraulically operated but counterbalanced by pneumatic rams to conserve energy. 98 per cent of the multiple welding equipment uses 45kVA, 50 per cent duty cycle transformers, with only one kind of power cubicle and of control panel. All requirements for welding cables are met by nine types, and pipe fittings are Aircraft General Standards throughout. The welding heads number two types and two sizes of each, in addition, there are self-equalising heads in which the electrodes are mounted on the cylinder and the inner ram of a two-stage air jack—the assembly is installed by the larger ram and the electrodes can come together at any point where the panel may lie.

An exception to the complete standardisation is afforded by the five-station automatic welding plant for under-bodies, which has different control panels and hydraulic services. Underbodies are assembled for both home and K.D. cars, and the resulting high throughput calls for a nearer approach to true automation. The machine, which makes 588 welds, accepts "Consul" or "Zephyr" components indiscriminately ; the four-cylinder and six-cylinder cars differ in wheel base, but the variations are confined to the engine bay, and the welds made in the automatic plant are behind the bulkhead. The K.D. sub-assemblies are not complete underbodies, but a switch, actuated by the optional panel as the press rises, selects the electrodes that are not required in the case of the K.D. version.

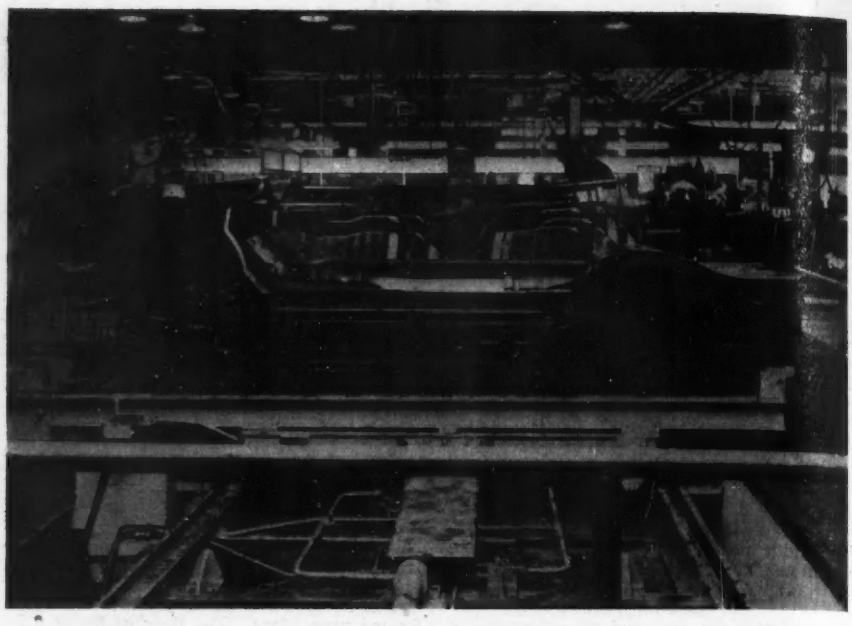


Fig. 4—A completed underbody being raised from the trolley; the electrodes under the flanges of the rear spring anchorage can be discerned. The panel in between these channels is omitted on "knocked down" products as is the engine bay. Notice the brake gear on the rear wheel of the trolley

The components are put together, as seen in Fig. 3, on a trolley which runs on two rails, one flat and the other of inverted V section. When the parts are in place, toggles clamping them are closed by motors energised by a wandering air line ; they can only be driven back over centre by another line. The dowels locating the trolley are then withdrawn and the trolley pushed off by a pneumatic ram. Underneath the trolley is a rack, which engages with motor-driven pinions between the rails ; each pinion has a free-wheel and it is arranged that the trolley always approaches faster than the pinion would drive it, thereby eliminating snatch on the drive ; the front 12in of rack is spring loaded to allow it to find mesh with each pinion. The trolley is brought to rest by wheel brakes operated by cams on the track. The rails in the foreground of Fig. 3 are moved sideways to present the trolley to the first press, and the trolley despatched by the ejector ram seen. When the trolley halts before the press a gathering ram draws it forward 14in to stand over the dowels ; this sequence is followed for all movements except along the return side, where it is driven by a succession of pinions at diminishing speeds. Along the return side there are unloading and two loading stations ; at the first of the latter the two pressed channels, like vestigial chassis members, that spread the rear spring loads into the structure, are laid in place.

With the trolley in the press, the underbody is raised to the welding heads and welding takes place ; only one stage can weld at one time. To achieve the required number of welds, "shuffle" is employed, the heads moving from one place to another up to 1¼in away between two welding sequences. In order to safeguard production against a breakdown of any press, both the first two presses perform sufficient welds for the assemblies to be finished by portable welders. The welding cycle in the heaviest loaded of the five presses takes about forty seconds, the time varying subject to the interlocks between presses.

True series welding is used in all stages, and as can be seen in Fig. 4, the trolley consists very largely of electrodes, which are positioned against templates to maintain the shape of the body accurately. One of the major advantages of this fully automatic welding plant is that the trolleys maintain their configuration indefinitely, whereas jigs moving from machine to machine other than on rails were subject to distortion.

All operations subsequent to completion of the underbody are manual, except that the complete body is dipped axle deep in a bath of black bitumastic paint to guard it against corrosion ; doors and similar structures have drain holes to render this effective on both inner and outer surfaces. Inspection of the welds is mechanical and random. Except for the simpler seams which are immersed in the bath of chassis black, all welds on the exterior panels are packed with weld sealer. Completed bodies are finished, glazed, and trimmed before leaving the works, having only to be carried on platform semi-trailers to the Ford Works.

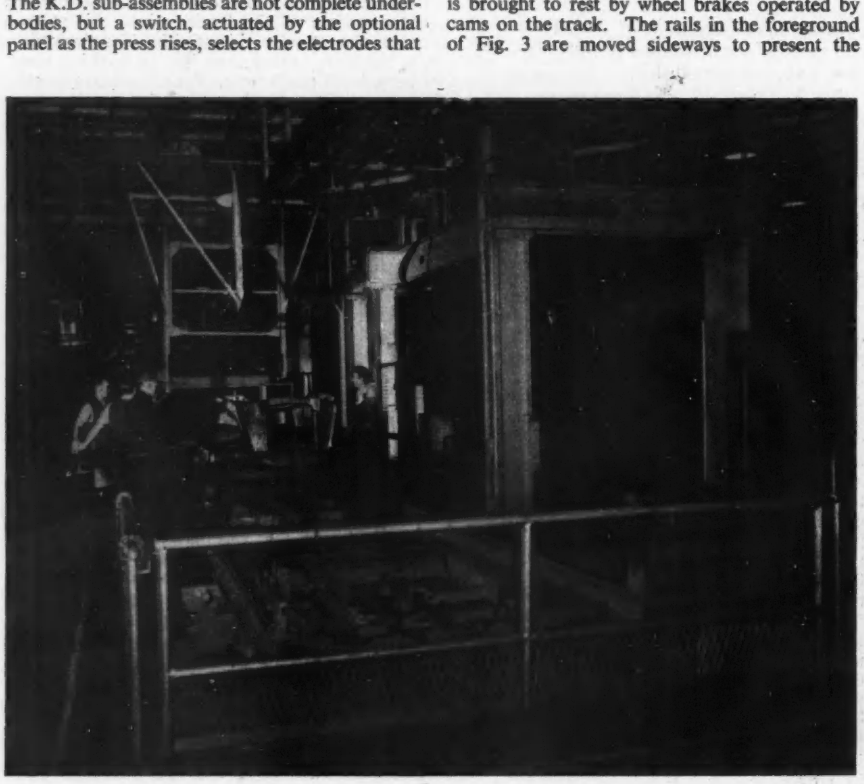


Fig. 3—The underbody welding press line ; one trolley is in the welding position in the first press and another is being loaded

MACHINE TOOL LUBRICATION.—A new book, *Machine Tool Lubrication*, forms a useful addition to the publications issued by Wakefield-Dick Industrial Oils, Ltd., 67, Grosvenor Street, London, W.1. This book gives first a brief history of the machine tool industry followed by an examination of the fundamentals of friction and lubrication. Subsequent chapters deal in detail with individual types of machine tools, their construction, operation and lubrication.

Factory for Heavy Tapered Roller Bearings

A large proportion of the capacity of a new factory opened at Daventry by British Timken, Ltd., just over a year ago, is devoted to the manufacture of large tapered roller bearings such as are used in rolling mills and other heavy industries. In this article we give particulars of the factory layout and production of bearings.

DURING the past few years a steadily growing demand at home and abroad for heavy tapered roller bearings such as are required for rolling mills and other large plant has necessitated an appreciable expansion of the manufacturing facilities for this class of bearing at the works of British Timken, Ltd. For this reason, when the firm was planning the construction of a new factory at Daventry some years ago, it was decided to devote its capacity mainly to the specialised manufacture of heavy bearings. Under this plan the firm's existing capacity for the smaller sizes of tapered roller bearings would be increased, and at the same time the necessary facilities required for making special and heavy bearings would be concentrated in one establishment. This new factory, the firm's fifth, was opened about a year ago and is now in full production, with its main capacity devoted to the manufacture of bearings from 20in diameter upwards, the present maximum diameter being some 10ft. As a matter of interest it should be mentioned that the first really large Timken bearing, with an outside diameter of 51in, was supplied some twenty-five years ago to a four-high mill in France which is still working.

We recently had an opportunity to visit the new works, where we saw, in addition to batches of smaller bearings, a large number of special large bearings of individual design in course of production. Many of these larger bearings are multi-row assemblies incorporating two, four and even six and eight rows of bearings. All these large bearings are made in a case hardened nickel steel to provide a hard wearing surface with a tough shock-resistant core.

The initial building layout at Daventry has been designed to facilitate expansion without interference with production. The works has for this purpose been arranged in the form of an "E" having a main transverse double bay 400ft long by 72ft wide, with three longitudinal double bays 288ft long by 80ft wide, opening off it on one side. The bays are of portal design, 18ft high to the crane gantries in the machining and grinding bays and 30ft high to the crane gantries in the heat-treatment bays, and large glazed areas in the walls and roof provide good natural lighting in all parts. All the main services of the factory, power, gas, water, compressed air and drains, are accommodated in large ducts between the buildings and are taken to the required stations within the bays through under-floor ducting. Ancillary service buildings not directly concerned with production have been sited at strategic points in the spaces between the bays. It should be mentioned here that the initial building layout has been found admirable for heavy bearing production and extensions which are now in hand follow the original plans in that the transverse main bay is being lengthened and the length of the three production bays doubled whilst the works is in full production.

The main transverse bay can best be described as the feeder and ancillary operation section to the three bays leading off it, which are mainly concerned with machining, heat-treatment, and grinding and assembly, respectively. Under the production flow programme raw materials and forgings for the bearings are fed into one end of the main bay from stores and an adjoining stock-yard. After inspection they pass into the machining bay shown in Fig. 1, which is mainly equipped with lathes and boring mills suitable for turning inner and outer races and rings and tapered rollers up to the largest sizes at present required by industry. One section of this shop is also equipped for the production of the jigs and fixtures used throughout the works, and an ancillary group of tool and cutter grinders in the main bay is engaged in the maintenance and production of the cutting tools required.

From the machine shop the bearing parts are transferred to the heat-treatment bay, one part of which is shown in Fig. 2. This shop is equipped for both pack and gas carburising. The two furnaces used for pack carburising can be seen on the left in our illustration and the gas carburising section is on the right. The furnaces in this gas carburising section, instead of being sunk below floor level as is the general practice, have been built up above the floor, and all loading and unloading is carried out by overhead chargers from a large gallery 13ft above floor level. By adopting this arrangement the need for large service basements below the building has been eliminated and all the ancillary equipment is readily accessible for maintenance purposes. The gas atmosphere plant serving these furnaces is situated in a small building in the space at the side of the main bay structure.

The gas-fired pack carburising furnaces, which are used mainly in the heat treatment of bearings above 4ft in diameter, have hearths 11ft square and 11ft by 5ft 6in respectively, and they are served by a floor mounted traversing charging machine. In order to keep the atmosphere of the hardening shop clear of dust all pot loading and unloading is carried out in a building adjacent to the main shop. In this shop, the carburising compound is prepared in rotary mix feed hoppers, and after loading the pots are transferred into the main shop on 11ft square mobile tables, one of which can

Fig. 1—Vertical mills in machine shop where inner and outer races and rings of large bearings are turned

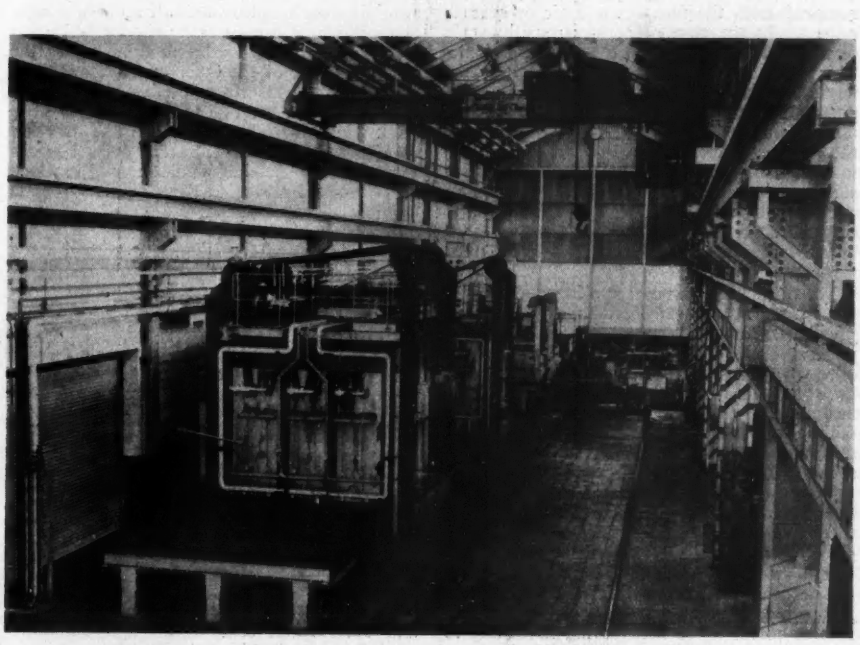


Fig. 2—Hardening shop with two large gas-fired pack carburising furnaces on the left. One of the transfer tables on which the pots are taken to and from the loading and unloading shop can be seen at the side of the foremost furnace

Fig. 3—Heavy medium line in the grinding shop. The roller grinding section of the shop can be seen in the background on the left

be seen in the left foreground in Fig. 2. From this table the pots are removed by the charging machine and inserted into the furnaces.

To produce the very deep case hardening called for on large bearings the carburising cycle in these furnaces can be as long as seven days, an average depth of case required on a bearing 4ft in diameter being about 0·20in, whilst for very large or heavy parts it may be increased to 0·25in. Parts up to 4ft diameter are usually treated in the gas carburising furnaces at the other side of the bay. These furnaces are gas fired through radiant tubes and the carburising medium is enriched cracked town gas supplied by the endothermic units in the adjacent building. To enrich this gas a controlled amount of butane gas is added through a mixing unit.

After the carburising cycle the pieces are removed from the furnaces and air or quench refined. In the case of pack carburising this operation is carried out in the potting shop, to which the hot pots and their contents are transferred using the charger and transfer table. The parts are then normalised by holding them at a temperature below the lower critical point of the case for a predetermined period and cooling in air. This operation puts the material in a suitable condition for the subsequent hardening process, which is carried out by heating parts up to 2ft 6in diameter in a continuous roller hearth furnace, and the larger sizes in the pack furnaces.

For quenching purposes the inner and outer races are mounted on special plug fixtures to prevent distortion. These fixtures consist of upper and lower cylindrical members which, to give adequate circulation of the quenching medium, have large slots round their circumferences. The heated part is placed over the slightly tapered ribs of the lower member of the fixture and, when the upper member is forced down on to it by means of a wedge, its correspondingly tapered ribs register firmly on the inner surface. The spaced ribs of the plug members thus hold the annular race in true roundness during quenching, whilst the gaps between the sets of ribs ensure good circulation of the quenching oil. The effectiveness of the quenching fixtures will be appreciated when it is pointed out that their use enables the roundness of pieces to be held during hardening to within about 0·010in on a 4ft to 5ft diameter, with a size tolerance of the same order of accuracy.

After hardening the races are degreased and checked for size and shape before being tempered in a large air circulating furnace to remove hardening stresses. They are then shot blasted to remove all scale before being transferred to the grinding section. Rollers for the bearings undergo the same heat-treatment as the inner and outer races, the smaller rollers being abrasive and polish barrelled, in addition to shot blasting, to impart the required finish on surfaces which are not subsequently ground.

As at present set out, this bay has sufficient space available for plant to permit a 60 per cent increase in its carburising capacity, and further extensions now in hand will double its existing capacity.

One end of the heavy machine section of the grinding shop is shown in Fig. 3. This section deals with the heavy races and the adjoining section to be seen on the left is equipped with lines of grinding machines for rollers. The grinding sequences for the inner and outer races of the bearings are generally similar. The flat faces are first rough ground, followed by the rough grinding of the inner and outer circumferences, and these surfaces are then finish ground in the same sequence. The amount of grinding stock allowed on the pieces is of the order of 0·020in to 0·060in on bearing parts between 20in and the maximum diameter for which capacity is installed. This relatively small grinding allowance for large annular parts indicates the necessity for maintaining roundness and size in heat-treatment. After every individual grinding operation the components are carefully checked with special gauges. Under the general order of accuracy attained in the final grinding operation wall thickness variation is held to within 0·0005in and parallelism of faces to within 0·0005in. At the end of the final grinding of the roller tracks a trial assembly is carried out with each set of inner and outer races, using a master set of rollers. In this test the components are tested for the mating of the track angles and for runout on the outside diameter and faces. On a typical trial assembly check the outside diameter runout would be of the order of 0·001in and the face runout 0·0015in.

A complete range of specially designed machines employed for the grinding of these large bearings includes a 72in vertical spindle rotary grinder for face and external grinding, internal and universal grinders of both the vertical and horizontal spindle types, capable of handling pieces from 120in outside diameter down to the smallest size made in the factory. Magnetic chucking is used on a majority of the work although special fixtures have been developed for grinding some of the very large pieces.

In the adjoining section of the shop the rollers are ground. The small rollers used in large numbers are supplied to the Daventry works from other of the firm's factories in a hardened condition ready for grinding, whilst large solid rollers 1in in diameter and above are made in a separate building at this works. These rollers are ground first on their tapered bodies on infeed centreless grinders. This is followed by the grinding of the two ends and, after a semi-finish operation on the tapered body, the important thrust end of the roller is spherically ground on specially designed machines. After subsequent polishing of the roller corner radii the body is then finish ground on infeed centreless grinders. Special machines are installed for grinding the profile of rollers either truly conical or crowned in one of a variety of ways to suit the specific application for which the bearing is intended.

Small rollers are made in large quantities, and after grinding they are machine graded following a close final visual inspection. The machine grading system is designed to ensure that the sizes of all the rollers in a group vary by no more than 0·00025in in diameter. The very large rollers, which may weigh 30 lb each, are ground individually to size, and here again the maximum variation between rollers in a group is not permitted to exceed 0·00025in.

Two forms of cages are used in bearing assemblies, the first being a pressing which may be used on bearings up to about 36in in diameter. These pressed cages are produced from steel strip in a variety of operations not carried out at the Daventry factory at present. In these cages the pockets to receive the rollers are pierced and the separating arms are then formed so that they conform to the profile of the roller body. In assembly this type of cage is spread diametrally and the rollers inserted in the pockets. The inner race is then fitted and the cage closed to its original size; this operation makes the inner race, the cage and the rollers into a single assembly. The cup or outer race is then applied to complete the bearing.

For the larger bearings fabricated cages are used for the rollers, and these cages are made up of two rings coupled together and spaced by hardened pins which pass through the rollers. It will be appreciated that in manufacture it is essential to ensure that the holes in the cage rings which receive the pins are accurately positioned for pitch-circle, spacing and angularity

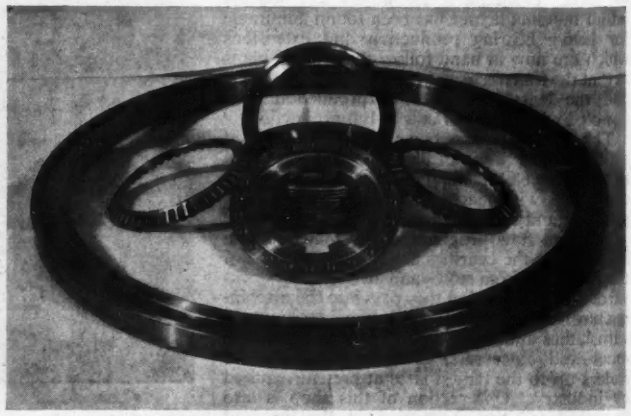


Fig. 4—Two case-hardened nickel steel taper roller bearings: the dismantled two-row bearing is to carry a variable-pitch propeller blade

so that the pins may pass freely and, at the same time, form a rigid assembly. In the course of assembly the rollers are placed on the cone of the inner race, the rings then being set in position and coupled together by insertion of the pins which are screwed in. After the bearing has then been run-in for a period and its accuracy checked the pins are welded in position with the exception of one, which is fitted with a locking device so that at any future time its roller can be removed to facilitate examination of the track of the inner race. For running-in purposes two machines of 100 and 200 tons capacity respectively have been installed in the main bay of the works. On these machines a predetermined load can be applied whilst the bearings are run-in for any required time to ensure that they run correctly.

After final assembly every bearing bore size, outside diameter, overall assembly height and degree of run-out is measured precisely and recorded. A similar record is made of the sizes of the various sets of rollers, the sizes also being marked on a non-operating surface of the rollers themselves. Dimensional records of every bearing made are carefully preserved at the works for future reference if needed.

As mentioned at the beginning of this article large bearings can be supplied in single rows or in multiples of two, four, six or even eight rows. In the case of these multi-row assemblies it is usual to fit spacers between the various inner and outer races to ensure that the correct running clearance is built into the bearings, and this involves a series of measuring operations to determine the size or thickness of the spacers. According to requirements either soft or hardened spacers can be fitted and they are made to the same close tolerances as the races.

All bearings after final inspection are dipped in hot protective grease and wrapped for despatch in any of a number of ways designed to give the fullest protection depending upon the method of shipment, destination, duration of probable storage and storage conditions on site.

A section of the main transverse bay of the works is partitioned off to provide office accommodation and an inspection and grading department for the small rollers. Above these sections is a wide gallery in which is situated the works laboratory and a toolroom.

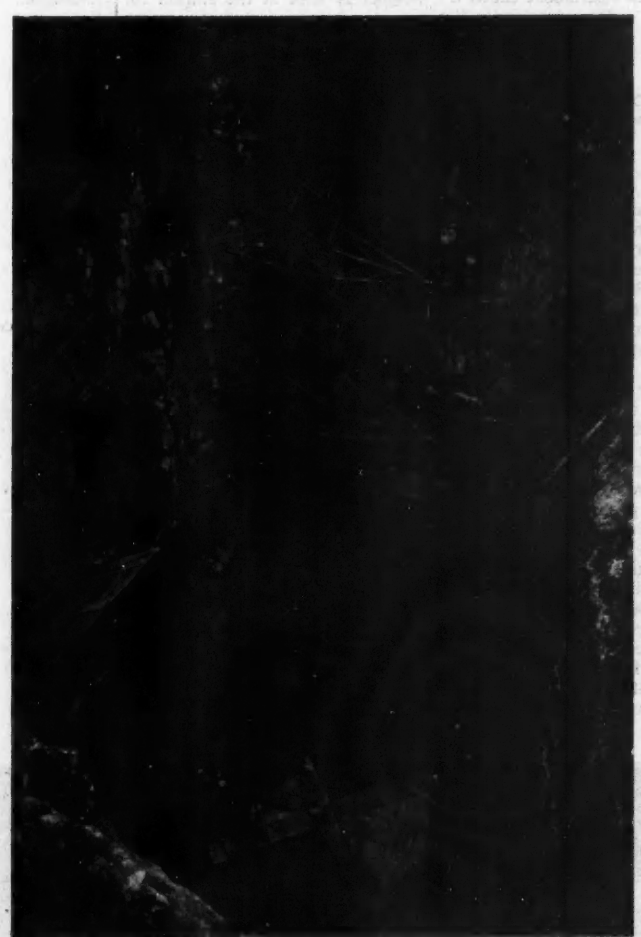
The technique of making bearings from case-hardening nickel steel allows special bearings of unusual interest to be fabricated, as we were shown in a subsequent visit to another of the firm's factories. Two such bearings for aircraft are shown in Fig. 4. The dismantled bearing illustrated, carries the blade of a Rotol propeller for a Vickers "Viscount." This is an application in which weight has an importance transcending even that of normal aircraft components, since weight in the boss increases the precession loads on the propeller shaft, and the weight of the cones increases the thrust on the bearing and the effort needed to alter pitch. Hence the races are formed as component parts of the assembly: the cup has a thread ground on its outer circumference, and incorporates a set of dogs by means of which it is screwed into the hub. One of the cones, and the set of smaller rollers, takes only tilting loads: the other is splined to the root of the blade and acts as a locking ring for the great hollow bolt which holds the blade. Selective hardening of the races, leaving the stressed parts tough, is obtained by copper plating before first grinding the races and hardening. The completed bearing is also copper-plated as a protection against stress corrosion. The cages are made of brass. The normal axial load on the bearing in service is 26 tons and it weighs only 5½ lb. When the bearing is tested under an axial load of 36 tons it begins to turn under an applied torque of 55 lb-ft.

The surrounding bearing shown in Fig. 4 is one of those referred to on page 365, September 14, in describing an aircraft wheel in which the whole hub was devoted to a disc brake. The bearing has a bore of 16½in, to admit the brake assembly, whilst its outside diameter is 18¼in.

STUD WELDING.—A publication entitled *An Introduction to Stud Welding*, by W. T. Amison, has been published at 3s. by the Association of Engineering and Shipbuilding Draughtsmen, Onslow Hall, Little Green, Richmond, Surrey.

Full-Scale Testing Station for Tall Structures

A TESTING station for carrying out loading tests on towers for electricity transmission lines and other tall structures has recently been brought into use by Stewarts and Lloyds, Ltd., at a disused quarry site near Wirksworth in Derbyshire. A testing station of this kind if built on flat ground requires the construction of at least two permanent towers of about the maximum height of the structures to be tested and with a substantial margin of strength and stiffness, so that horizontal test loads can be applied to the top of the tower under test in two directions at right angles. The Wirksworth station makes use of a unique site where construction of such permanent towers is not necessary. The station is situated in an old limestone quarry which forms, in effect, a hole about 100ft by 60ft in cross section, with substantially vertical faces, and about 150ft in depth. The quarry is entered through a narrow cleft in the rock; rising ground above it will enable towers up to 200ft in height to be tested. Anchor bolts can be fitted into the rock face as required to secure any given loading condition. The appearance of the testing station is shown in the above illustration; the cleft giving access to the station is shown in the right-hand background of this illustration, partially obscured by the wire mesh hung on the rock face to catch any falling stones.



Wirksworth testing station. A tubular steel tower for the 275kV super-grid is shown under test. The tower is about 130ft in height

Apart from the convenience of the site from the point of view of loading the towers, it also gives substantially still-air conditions for testing, an important point when wind loading is one of the main factors simulated in the tests. One of the promoting firm's subsidiary companies, Tubewrights, Ltd., has been developing designs of transmission line towers in tubular steel, and the principal reason for the station was to provide the testing facilities which these new designs required. We understand, however, that the station will be available to any organisation which has work of this nature to carry out.

Loads up to 30 tons can be applied at each of the anchor points. Eye-bolts can be grouted into the floor or walls as they are required, or, alternatively, a bridle can be fixed between two anchors to give an intermediate anchorage point. Pull-out tests on various kinds of anchor bolts were carried out, and as a result, on a single eye-bolt with a threaded end was selected for use, in tests, this bolt failed at 94 tons, the eye of the bolt failing, the anchorage proper remaining secure. The concrete base—cruciform in shape—to which the towers are attached can also be seen quite clearly in our first illustration. Bolts can be threaded into sockets cast into this base, such that a degree of flexibility sufficient to pick up practically any tower footing is achieved.

LOADING AND INSTRUMENTATION

Our first impressions during a recent visit to the Wirksworth testing station concerned the unique advantages of the site. There is also considerable interest in the instrumentation installed for testing. The design of this equipment has involved some original development work. All loading and measurement is controlled from a central point, and signals of loads and deflections are shown on dials in the control room, where photographic records can be taken at appropriate intervals or the complete test registered on a tape recorder.

Loads are applied by cables and winches. There are twelve winches, each powered by a 2 h.p. motor and geared to give a rope speed of 1¼ft per minute. Thus the motor of each winch runs at 960 r.p.m., but the main drum makes only half a revolution in one minute. The maximum load on each winch is 5 tons; but with a multi sheave block up to 30 tons and, of course, slower cable speeds can be obtained. Thus the basic arrangement allows for twelve 30-ton loading points, with additional possibilities by coupling a number of winches together or using one winch serving several points. This method of applying loads was considered superior to a dead-weight arrangement; loads are more easily controlled at the failure of a tower, and can be sustained or released as the tower deflects, with greater facility. The winches are installed in a building running along one side of the quarry; the control room is immediately above them;

and they can be controlled by push buttons or remotely from the control room. The drives in the control room are grouped into two sets, each covering six of the winches. Deflections at ten points can also be recorded.

The control room also has equipment for strain gauge measurements and vibration tests. There is an observation point in a hut at the top of the quarry, with telephone and recording dials connecting with the control room. Also, weather conditions can be recorded.

Load and Deflection Measurement

The basic measurements of load and deflection are indicated by instruments evolved for the particular conditions of these tests. The test may be in progress for some time, and conditions imposed by the weather and by handling may be seen. Further, it was considered that normal 50 c/s power should be used for these instruments.

Deflection is measured by stranded steel wires, attached to the structure at appropriate points, and each passing over a pulley in a pedestal gauge, where a weight is hung inside the tube of the pedestal, and attached to the pulley, to keep the tension in the wire constant. Rotation of the pulley is measured electrically and indicated in the control room. This apparatus is considered to be sensitive enough to detect a movement of one twentieth of an inch, and all readings are considered accurate to within about a tenth of an inch.

Load is measured by an instrument called a "pull meter," is which built as a link and is fastened between the load point and the loading cable.

Although it makes use of a well-known principle, development into a practical instrument is noteworthy. Extension of the tubular steel outer case of the instrument, is measured by a differential transformer. The left-hand end of the instrument carries a probe with a small coil at the end of it; the right-hand end carries the primary winding at the tube centre with a secondary on each side, these secondary windings being connected into a potentiometric bridge circuit. When the small coil is disposed centrally in relation to the three coils surrounding it, the bridge is in balance. Movement of the coil induces out-of-balance current, and hence calibration in terms of load is possible. Transient temperature effects have been dealt with by filling the cylinder with an inert oil, so that, in conjunction with the perforated metallic mounting illustrated, an even temperature is maintained; also the probe carrying the small coil is of composite construction to give it the correct effective coefficient of expansion.

It is pointed out that the "pull meter" is weatherproof and robust, and it operates on normal 50 c/s electricity supply, using a large current compared with a strain gauge. Errors are stated to be within ±1 per cent of full load, and sensitivity one part in a thousand. The instruments are made in sizes capable of recording up to 2, 5, 10 or 30 tons. An arrangement of weights is kept at the station for calibration.

Surface Protection by Coating

A PROCESS affording thermal, erosion and electrical protection to metal and other surfaces is now being carried out by Norton Grinding Wheel Company, Ltd., Bridge Road East, Welwyn Garden City, Herts. The severe erosion that occurs on steel parts such as rocket motor nozzles, where a throat of 4in diameter may be enlarged ¼in in ten seconds' running, caused the Norton Company of Worcester, Massachusetts, to investigate possible new materials and processes for high-temperature operation, with particular reference to rockets, and one outstanding result of this programme was the discovery of the method of applying protective coatings of high melting point pure oxides, spinels and other materials to metal, graphite and other surfaces. This is now known as the "Rokide" coating process. This process is the subject of British Patent No. 745,257, of August 7, 1953 (published February 22, 1956).

Ceramic protective coatings are not new and a number are available which are very effective at temperatures under 1000 deg. Cent. These are usually enamel compositions and applied by spraying the powdered preformed enamel on to a cleaned metal surface, then melting the enamel by placing the coated part in a furnace. The use of such coatings may be limited for three main reasons:

(1) The enamel must have a melting point lower than that of the surface to which it is applied, and imposes this limitation on the operating temperature.

(2) The base material may be detrimentally affected by the enamel furnacing operation.

(3) There may be limitations as to size or design which could be handled in furnacing.

The "Rokide" process is carried out on the cold base material and even an oxide such as zirconia, with a melting point of about 2500 deg. Cent. can, it is stated, be satisfactorily coated on lower melting point metals such as aluminium and magnesium. The temperature reached by the article during coating is unlikely to be detrimental and coatings have actually been applied to certain synthetic resin materials without visible charring. The coating thickness can be controlled quite closely and, if necessary, it can be varied for particular locations on an article. In addition to metals other materials which can be coated satisfactorily are solid carbon in various forms, glass, ceramics and asbestos compositions; in fact, no inorganic constructional materials have yet been submitted which could not be coated. The only limitations as to size which could be visualised lie in the lower limit—it is not practicable at present to coat the inside of tubes or holes less than 3in diameter if the length exceeds four times the diameter and, of course, accessibility to a spray gun is a necessary requirement.

Although it is possible to use a wide variety of coating materials, experience has shown that requirements are likely to be suited by one of three materials which have, therefore, been adopted as standards. These are "Rokide A" (alumina), "Rokide Z" (zirconia), and "Rokide ZS" (zircon), the properties of which are given in Table I:

Table I—*Properties of "Rokide" Coatings*

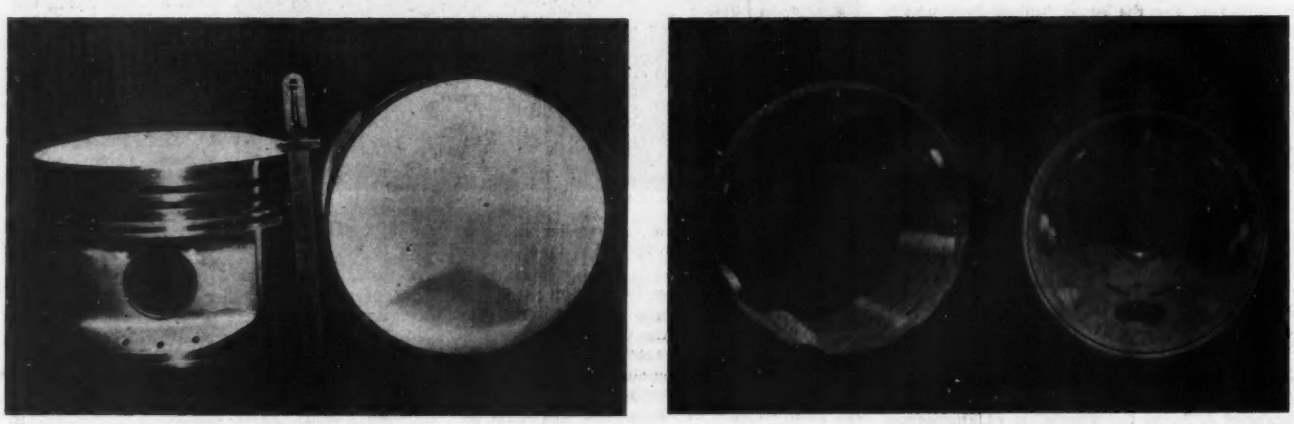
	"Rokide A"	"Rokide Z"	"Rokide ZS"
Chemical composition	98·6 per cent Al_2O_3	98 per cent lime stab ZrO_2	65 per cent ZrO_2 and 34 per cent SiO_2
Crystal form	Gamma type	Cubic ZrO_2	Cubic ZrO_2 silica glass
Bulk density, g/cc ...	3·2	5·2	3·8
True	3·6	5·7	4·15
Total porosity	8 to 12	8 to 12	8 to 12
Thermal conductivity	19	8	15
Total emissivity	0·3-0·4	0·3-0·4	0·3-0·4
Melting point	3600 deg. Fah.	4500 deg. Fah.	Glassy phase at about 3000 deg. Fah.
Colour...	White	Tan	Tan

Table II shows the principal properties compared with a stainless steel:

Table II—*Properties of Oxides and Stainless Steel*

	Aluminium oxide	Zircon	Stabilised zirconium oxide	Stainless steel
Thermal expansion (×106/deg. Fah.) from 70 deg. to 2550 deg. Fah.	4·3	2·3	6·4	12·2
Thermal conductivity (B.Th. U./hr./ft²/deg. Fah.), mean temperature of 1500 deg. Fah.	19	15	8	185
Density (g/cc)	3·2	3·8	5	7·8
Melting point, deg. Fah.	3600	3000	4500	2600
Hardness, Knoop ...	2000	1000	750	400

The coating operation itself is simple and a previously unskilled operator can be trained in a few days. The coating materials are in rod form and an oxy-acetylene flame spray gun specially designed for the process is used. The rod is fed at a constant rate through a central hole in the burning nozzle, which is surrounded by a cap suitably spaced to pass compressed air. The rod becomes molten in the burning gas and small particles are driven off at high velocity by the air blast, striking the surface to be coated while still in a plastic condition. At the same time, the passage of the air over the burning nozzle prevents the equipment from overheating. The rod is fed between two opposing drive rollers which are driven by a constant speed electric motor through a variable reduction gear. The thickness of coating possible does not appear to be limited and coatings of 2·5mm thickness have been applied. The rate of coating varies



Examples of "Rokide." (Left) "A" on a piston crown; (right) "Z" in a gas turbine combustion chamber

according to the material used and for a coating 0·010in thick may at the present time be from 70 to 150 square inches an hour ; for example, alumina is near the top figure while zirconia is very much slower.

To promote adhesion, which is largely mechanical, a metal base being coated is first prepared by roughening with a shot-blasting operation ; with correct surface preparation the coatings are stated to be tenacious. Uniform quality and strength are maintained throughout the whole depth of coating, and, because the process requires that each particle must be molten before it can be transferred to the coating surface, consistent quality is ensured. It is not possible for the coating to be weakened by the incorporation of unfused or partially fused material.

The nature of the process is such that molten droplets of the coating material freeze on the surface of the metal and on each other to form an interlocking layer structure of low porosity, and this layering effect apparently increases the flexibility of a normally rigid brittle material. It is claimed that a thin sheet coated with " Rokide " can be bent and flexed considerably without breaking or cracking the coating. In addition to this mechanical flexibility, the ability of the coating to adjust to stresses also results in a very high resistance to thermal shock. Impingement of a flame at about 5000 deg. Fah. on a 0·010in thick coating for two or three seconds can be sufficient to melt the coating, but subsequently, although the fluidised surface may show fine cooling stress cracks, the coating adjacent and underneath the molten surface is still intact. There are possible limitations associated with the slight porosity of these coatings. In some cases, with a long enough time, corrosive agents will permeate through the coatings and attack the base material ; such attack will be much slower than for uncoated material. Under thermal cyclic corrosive condition it is possible that reaction products may form on the base metal underneath the coating and, in time, these can inhibit the movement of the coating with the base and repeated thermal expansion may then cause loosening. This possible effect is mainly associated with convex surfaces such as the outside diameters of tubes and sharp edges and it should be kept in mind that ceramics are brittle materials with compressive strengths about ten times greater than their tensile strengths, and tensile stresses on the coatings due to thermal expansion are likely to be more severe on such convex surfaces.

Although the process was primarily developed for thermal protection, the character of the coatings is such that a much wider field of application is provided. For example, the hardness of " Rokide A " is comparable with that of the alumina used in grinding wheels, and it can therefore be used to provide a wear-resistant surface on metals and other materials. The coatings themselves are unaffected by most chemical agents and stable in combustion atmospheres. The electrical insulation property of the coatings is high through a wide range of temperature.

The greater thermal protection is given by " Rokide Z " (zirconia), but if temperatures in excess of 1200 deg. to 1300 deg. Cent. are accompanied by severe erosive conditions " Rokide A " (alumina) may be required. Examples of each are illustrated. In certain cases " Rokide Z " has provided the principal thermal barrier, while a thinner superimposed layer of " Rokide A " assists in taking care of erosion. " Z," however, is about twice as costly as the other coats. Where erosion or wear resistance in any form is the prime requirement, " Rokide A " is usually the first choice, although " Rokide ZS " (zircon) may often be satisfactory, particularly where there is no considerable thermal problem. For example, wear-resistant bearing or sliding surfaces for operation in contact with corrosive fluids or other corrosive media may be more satisfactory in " Rokide ZS," in which possibly half the small total porosity is present as closed pores. All coatings are electrically non-conducting, although the resistance of " Rokide Z " decreases rapidly above 1200 deg. Cent. For high-temperature electrical insulation " Rokide A " is recommended and " Rokide ZS " may be considered when relatively low temperatures are concerned.

Voltage breakdown tests carried out on normal coatings 0·002in, 0·005in and 0·010in thick under normal atmospheric conditions gave figures of approximately 500V, 1000V and 1500V respectively, but these figures can be increased considerably if the porosity is first sealed by applying a silicone resin varnish to the coating. If operating temperatures should exceed the decomposition temperature of the varnish, the residual decomposition products do not detrimentally affect the electrical properties of the " Rokide " coating.

The patentees observe that the optimum tenacity is only obtained on a surface which is capable of being appreciably roughened by shot blasting. In some cases it has been found that a preliminary sprayed metal coating can be very effective in improving the adhesion of the " Rokide " coating.

Although the coatings as applied are relatively rough—with a " Talysurf " finish probably measuring 100 to 200 micro-inches—they can be ground to precision tolerances with a silicon carbide grinding wheel. Grinding is usually done dry with very light feeds. A very high condition of surface finish can be obtained by further lapping and in one particular case a finish was obtained commercially with a flatness measured at 3 å.u. Irregular and awkward surfaces can be smoothed with abrasive cloth about 120 grit. Grinding with diamond wheels is very effective and is preferred for the first grinding operation if a very high final finish is required.

Coal Cutter Loader

We illustrate on this page a cutter loader which can be used in coal seams from 18in to 3ft in thickness which has been designed by Mr. William Morgan, agent and manager, and Mr. A. A. Senior, the unit engineer, of Hartley Bank Colliery, near Wakefield. The equipment consists of a longwall coal-cutting machine with a 5ft cutting jib and chain. At the end of the cutting jib there is a fitted mushroom pulley with cutting picks by which a vertical cut is made up the coalface at the end of the undercut coal.

Cutter loader for coal seams from 18in to 3ft thick

The height of this mushroom pulley is in accordance with the thickness and the nature of the parting between the coal seam and the roof.

The loader end of the machine consists of a normal coal-cutter jib which can be fitted with either picks or flights. This jib is driven by a sprocket wheel on the top of a vertical shaft which is connected by a chain to a similar sprocket on an extension of the vertical shaft driving the normal jib of the coal cutter. A rigid plate bridge couples the cutting and loading ends of the machine together and encloses the driving chains. Through the space below this bridge the coal is passed on to the face conveyor belt. For this purpose a heavy inclined plate is fitted to the loading jib to act as a plough and push the coal into the space between the cutting jib and the loader. The coal is thereby carried through the bridge to the face belt by the picks of both the cutting jib and the loader jib.

The machine cuts and loads in either direction of travel, the plough being changed in the stable at either end of a coalface. The machine is pulled along the coalface by rope and for its use it is stated that neither a prop-free front nor special roof bars are necessary. It can be used effectively in conjunction with a bottom belt face conveyor.

Plastic Coating of Metallic Articles

A demonstration of spraying and dipping techniques for the application of plastic protective coatings to metallic articles was recently given by the Schori Division of F. W. Berk and Co., Ltd., Brent Crescent, London, N.W.10. With these techniques a range of thermoplastic materials such as nylon, polythene, thickol and shellac can be applied to articles of all shapes to provide a protective coating with the corrosion resisting, electrical insulating and other properties of the plastics.

For plastic spraying purposes the firm has developed a new pistol for powder-flame spraying without the use of a solvent. With this pistol the metallic surface is first heated, using the normal flame, and then, on a further depression of the operating lever of the pistol grip, plastic in powder form is fed under pressure into the flame. In its passage through the flame to the workpiece the powder is melted so that on impinging on the heated metal it flows evenly to form a continuous protective coating.

Another equipment developed for applying the coatings consists of a duplex oven installation with a centrally disposed powder spraying chamber. In this case articles are preheated in an oven and then transferred to the spraying chamber, where powder is blown on to the required surfaces, through a nozzle connected by a flexible hose to a container. Excess powder in the atmosphere of the chamber is recovered for re-use in the bag filter of the chamber exhaust system. Articles after spraying are transferred to the second oven for fusing of the protective coating. In a third method using similar equipment, the articles are heated in the first oven above the normal melting temperature of the plastic powder. They are then dipped in a hopper in which the powder is kept in a fluid condition by constant upward flow of air fed in by jets in the base of the hopper. This " fluidising " of the powder maintains it in a free condition so that the articles can be easily plunged into the hopper, where they are completely surrounded by the powder, which penetrates into all hollows and corners. When the articles are removed from the hopper they are placed in the central chamber between the ovens and the excess powder is blown off by a compressed air jet. The articles with the adhering semi-molten film of plastic are then placed in the second oven, where the plastic is fused on the surfaces.

An automatic plant has been developed for use with repetition articles and wire work which have to be coated all over with a plastic. In this plant the articles are suspended on an overhead conveyor which first takes them into the oven of a preheating section. On the next movement of the conveyor the articles are carried into a second oven where their adhering coat of plastic is fused, and from here they pass to a cooling section and an unloading station.

In all these processes a plastic coating of about 0·015in is normally applied although, if required, thicker coatings can be made.

Portable Log Mill

A PORTABLE log mill of special design, which is fitted with twin circular saws, has been built by Stenners of Tiverton, Ltd., Tiverton, Devon, for Steel Brothers (Tanganyika Timber), Ltd. It is designed for quick and easy transport between sites in Tanganyika, and to keep its size and weight within readily portable limits it is built up on three trailers which are separated during movement and keyed together for use. Each trailer has screw jacks built into its frame to facilitate the removal of the transporting wheels and bogie and to lower the working frames complete with equipment to ground level.

The mill is designed to handle logs up to 20ft long and 45in in diameter, and it can be seen in operation in the photograph reproduced on this page. The centre trailer frame, which carries all the working equipment of the mill except the log carriage, is set centrally at right angles to the other two trailers. These two trailers have machined vee and flat steel rails bolted on top of their outer longitudinal members for supporting the log carriage when the machine is in operation. The main trailer has the saw assembly and a 120 h.p. motor for the main drive mounted on it, together with a small subsidiary motor for the variable-speed log carriage drive. Electric power for the equipment is supplied by a separate diesel alternator set, and the switchgear, junction boxes, &c., for the ancillary equipment of the mill is mounted on the main trailer frame.

The main motor drives the bottom saw spindle at 430 r.p.m. through a vee rope, and this drive is transmitted from the bottom spindle to the top saw spindle through pulleys and a flat belt at 860 r.p.m. The bottom spindle carries a 72in diameter inserted tooth saw and the top spindle a 32in diameter inserted tooth saw. No vertical adjustment is necessary for these inserted tooth saws, but means are provided for setting the top saw longitudinally in line with the lower saw.

The log carriage is traversed backwards and forwards along its rails by an endless wire rope wound round a rope drum. This drum is driven from an electric motor through reduction gears and a friction variable-speed unit. With this form of drive the carriage is arranged for a variable forward feed speed and a constant return speed under the control of a handwheel, which the sawyer can be seen operating in the illustration. The log is fed towards the saw for different thicknesses of cut by a hand lever operated by a man riding on the carriage platform. An index plate provides accurate carriage cross setting for board cutting and a scale indicates the thickness of cut.

Portable log mill installed on site ready for use. This mill handles logs up to 20ft long by 45in diameter and is designed for transport on three trailers which provide the foundation elements on site

Electrostatic Air Filter

AN electrostatic air filter has recently been introduced into the United Kingdom. This filter ensures air free of dust, dirt, smoke, bacteria, and other airborne contaminants.

The filter, made by Trion, Inc., McKees Rocks, Pennsylvania, utilises the principle of electrostatic precipitation and collects all airborne contaminants down to one-hundredth of 1 micron in size or less. Bacteria, it should be noted, average approximately 1 micron (=0·001mm).

The measurement of the efficiency of the "Trion" filter is based on a photometric test instead of a weight test. Weight tests ignore the large numbers of small particles present in the atmosphere which, in spite of having very little weight, have high soiling properties and cause serious trouble in many processes. Mechanical filters may therefore have an efficiency of 99 per cent on a weight basis, but would still allow many of the finer particles to pass through.

In the "Trion" filtering process all particles in the air receive a positive electric charge as they pass through a high-voltage ionising screen. The charged particles are then attracted and adhere to the negatively charged collecting plates which form part of a series of parallel plates, charged alternately positive and negative. Periodically, depending on the dirt content of the air, the dirt must be removed from the collecting cell. This is accomplished by opening a valve which sprays the cell with water and washes the dirt into a drain.

The ionising collecting cells, each of which is a complete unit, are rigidly constructed of aluminium for corrosion resistance and ease of handling. The framework of the cell incorporates a venturi nozzle approach, which prevents by-pass of uncleaned air and permits the installation of insulators out of the air stream. Fine tungsten ionising wires are suspended between tubular electrodes and mounted in front of a series of vertical parallel aluminium plates, which are accurately positioned and rigidly held to uniform spacing. All ionising wires are the same size and preformed for easy replacement.

The "Trion" filter is stated to be essentially for applications in which the total dust loading is substantially less than that occurring in heavy industrial plant, but which is sufficiently high to have deleterious effects. It is being marketed in the United Kingdom by W. C. Holmes and Co., Ltd., Turnbridge, Huddersfield (P.O. Box B.7), and Harris Engineering Company, Ltd., York Works, Browning Street, London, S.E.17. Holmes is handling industrial applications and Harris commercial applications.

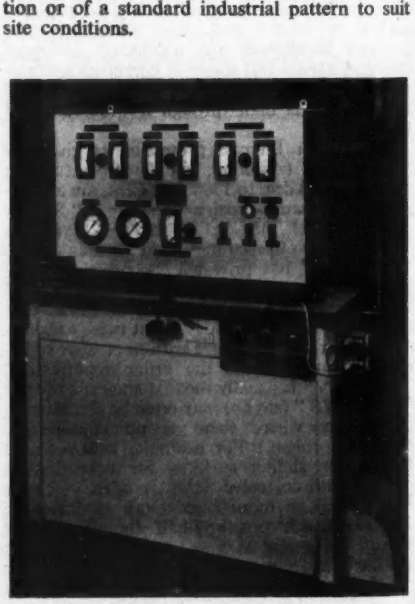
Automatic Control and Warning Equipment for Air Compressors

A CONTROL and protection panel for air compressor installations, introduced by Holman Brothers, Ltd., Camborne, Cornwall, is designed to comply with the new National Coal Board (Production) Codes for reciprocating compressor installations. In addition to providing temperature and pressure data for both air compression stages, its equipment also records cooling water temperature and lubricating oil pressures and temperature. Protection is provided by an automatic shut-down system operating from the air delivery thermometers, oil pressure and cooling water lines, whilst unrectified faults in the panel itself also stop the set.

A typical panel is illustrated below. It is fitted with three pressure gauges, one recording the air delivery pressure from the first stage of compression, a second the final air discharge pressure, and the third the lubricating oil pressure. Dial thermometers record conditions at the compressor air inlet, first stage air delivery, second stage air inlet, point of final air delivery in the cooling water system, and the lubricating oil reservoir.

Thermal protection is provided by two automatic thermostatic switches, one to each of the two compression stages, and these switches are activated by sensitive phials inserted in the air delivery streams. An excessive air temperature causes the appropriate thermostat switch to open and break the no-volt coil circuit of the compressor motor starter, to stop the plant. A flow switch, fitted to the compressor cooling water service, similarly stops the machine in the event of an interruption in the cooling water flow. For protection against a possible oil pressure failure a pressure switch is inserted in the lubricating oil circuit, to stop the compressor should the oil pressure substantially decrease or fail.

Each of the protective instruments is fitted with a red warning lamp to indicate the source of the fault, and an audible alarm is provided. These panels can be either of flameproof construction or of a standard industrial pattern to suit site conditions.



Typical panel of the automatic control and warning equipment for air compressors

Industrial and Labour Notes

Petrol and Oil Prices

On Tuesday, the Chancellor of the Exchequer, Mr. Harold Macmillan, made a statement about the decline in gold and dollar reserves, the latest monthly figures having shown a fall of 279,000,000 dollars. The Chancellor said that this country must fortify its own economy on which recent events had put new strains.

In the course of his statement, the Chancellor said it had been estimated that, when petrol rationing took effect, the revenue would drop at a rate of £6,000,000 a month, and it was essential to the Exchequer that that should be made good. It was therefore proposed, as an emergency measure, to raise the customs duty on petrol and other light hydrocarbon oils and on derv by 1s. a gallon; that meant that the duty would be increased from 2s. 6d. to 3s. 6d. a gallon. That, the Chancellor continued, would be in addition to the increases in the wholesale and retail prices of those products which the oil companies were making on account of higher costs, i.e., wholesale price increases of 3½d. a gallon on motor spirit and 3d. on derv, with an additional 1½d. a gallon in each case on retail sales. There would be corresponding adjustments in the rates of duty on indigeneous oils and on one or two minor products which traditionally moved in step with the main rate of petrol duty. The increase in duty, the Chancellor said, would bring in extra revenue of about £30,000,000 in the remaining four months of this financial year. The Chancellor added that he regarded the new petrol tax as a temporary measure during the present oil shortage.

The Factory Inspector's Report

This week, the annual report of the Chief Inspector of Factories has been published, (Cmd. 8, H.M. Stationery Office, price 9s.). It covers the year 1955, and, as is customary, deals with a number of topics concerned with health, welfare and safety.

In his introduction to the report, the Chief Inspector, Sir George Barnett, says that, compared with 1954, the factory population increased last year by 2·5 per cent, the number of factories with power increased by 0·4 per cent, and the number of accidents in factories (though not the accident rate) increased by 1·2 per cent. Actually, the accident rate in 1955 (1950=100) was, at 89·2, the lowest yet recorded. In all, last year, there were 188,403 accidents reported from all premises covered by the Factories Act, and through those accidents there were 703 deaths. The number of deaths at building sites and works of engineering construction has tended to decrease, the Chief Inspector says, but last year progress of that order was not so evident in factories.

In some comments on the design of factory premises, the report says that because the building of single-storey factories in the Midlands was fast producing a state of affairs where there would be no room for further industrial development, the Midland Regional Board for Industry has sponsored research into the relative costs and merits of various kinds of single and multi-storey factories. It is hoped that some standardisation of a few definite designs of factory buildings will result, for which there will be adequate data as to building materials, heating, lighting, ventilation, welfare facilities, and, not least important, costs. The report also makes reference to the fact that throughout last year mechanisation and automatic control of factory processes of all kinds were becoming more and more widespread. The Chief Inspector of Factories thinks that the cumulative effect on production and on working conditions of a number of such changes in relatively small items was probably much greater than that of the more obviously impressive examples of full automation in the larger plants. Whatever the plant or the degree of automatic control, the report adds, it is always important to ensure that control mechanisms have the characteristics necessary for safety.

About accident prevention organisation, the Chief Inspector remarks that, unless there is a "genuine and continuing interest" shown by top managements, accident prevention schemes, however excellent on paper, are doomed to stagnation and ultimate failure. On the subject of training, the report says that there is a "widening appreciation" in most industries of the importance of including training in safety, health and welfare in all training for production and management. Last year there was ample evidence, the report records, of the benefits accruing from initial training and from refresher courses for professional safety officers and others engaged in the work of preventing industrial accidents.

Engineering Wages

On Thursday of last week, the Engineering and Allied Employers' National Federation informed representatives of the Confederation of Shipbuilding and Engineering Unions that it must reject the claim for a 10 per cent wage increase in the engineering industry. The claim, which was submitted a few weeks ago, was formulated after a resolution in favour of a new wage demand had been passed at the union confederation's annual conference at the end of August.

In conveying the employers' decision to the union leaders, Mr. F. C. Braby, chairman of the Employers' Federation, recalled that the unions had been warned in recent years about the danger of frequent wage increases. What was necessary, he said, was that the unions should help to create a period of stability. In a detailed statement on the arguments advanced by the unions, the director of the Engineering and Allied Employers' National Federation, Mr. Macarty, emphasised that earnings in engineering compared favourably with those in other industries. Employees, he said, were sharing in the industry's prosperity, and, furthermore, in recent years, wages had risen more quickly than prices and production. Another comment made by Mr. Macarty concerned overtime. The unions, he stated, had claimed that less overtime was being worked, yet 62 per cent of the skilled men and 73 per cent of the unskilled men in the engineering industries were regularly working overtime.

Changes in Wage Rates

The Ministry of Labour says that, during October, changes in wage rates which came into operation in the United Kingdom resulted in an aggregate increase estimated at approximately £53,000 in the weekly full-time wages of about 313,000 workpeople, and a decrease of £13,000 for 144,000 workpeople. The decreases operated under sliding-scale arrangements based on the index of retail prices.

Those receiving increases in October included some workers in the building industries, where wage rates rose by ½d. an hour for craftsmen and labourers affected by the "upgrading" of certain districts of England and Wales. In the iron and steel industry, there were some small wage increases payable under sliding-scale arrangements based on the index of retail prices. Workers in the metal finishing trades in England and Wales also received increases, in the minimum wage rates, of 2½d., 3d. or 3½d. an hour, according to grade, for men, and 2½d. an hour for women.

In the first ten completed months of this year, the Ministry says, changes in wage rates resulted in an aggregate weekly increase of £6,333,600 in the full-time wages of about 12,031,500 workpeople. In the comparable period of last year, there was a net increase of £4,712,000 in the weekly full-time rates of wages of 11,505,000 workpeople. At the end of October this year, the index of rates of wages (June 30, 1947=100) stood at 164 for all workers. At the end of last year, the index number was 153.

Pensions for Professional Engineers

The Engineers' Guild has given some details this week of a group insurance scheme which it is starting in order to provide adequate pension arrangements for professional engineers. The Guild's view is that the professional engineer should be able, if he so desires, to move from one big operation to another, either at home or overseas, even though it may involve working for different firms or as an independent consultant.

The pension scheme has been devised in co-operation with a firm of pension advisers and a life insurance office. One of the main points of the scheme is that it ensures that the professional engineer can secure a continuous pension and insurance cover throughout his career whatever changes take place in his employment. Furthermore, where desired, the employer can pay some or all of the contributions, a matter which it is believed will appeal particularly to the smaller firms who wish to attract professional engineers by offering good pension arrangements. The Guild says that medical evidence about health will not be required for the first £2000 insured, and that this is a figure which may be increased at a later stage. Moreover, the age at which a pension becomes payable can, within certain limits, be selected.

The scheme is open to all members of the Institutions of Civil, Mechanical or Electrical Engineers, aged between twenty-one and sixty, and resident in approved countries. Information concerning it can be obtained from the Engineers' Guild, 78, Buckingham Gate, London, S.W.1.

Staggering of Working Hours

Last week, the Minister of Transport and Civil Aviation stated that he had set up a new committee "to further the staggering of working hours in Central London." The committee is to be "more executive than advisory," and will be presided over by Mr. Fitzgerald, who is the chairman of the Transport Users' Consultative Committee for London.

The committee's terms of reference are as follows: to consider and to set in train further measures for the staggering of working hours so as to relieve congestion at the peak periods on the services to and from Central London provided by London Transport and British Railways; to review changes in the daytime population of Central London, particularly those arising from the erection of new buildings, and to endeavour to avoid any consequent increase of congestion; to recommend to the Minister of Transport and Civil Aviation any measures which it may consider desirable but finds itself unable to initiate. The secretary to the committee is Mr. G. T. Tippett, 22, Palace Chambers, Bridge Street, London, S.W.1.

In recent years there have been two campaigns in order to promote the staggering of working hours in Central London. The first of them was conducted in 1947 and 1948, and achieved a certain amount of success, although that achievement was hampered by the increase of employment in Central London. The second campaign was started two years ago, when the Minister of Transport referred the problem to the Central Transport Consultative Committee set up under the Transport Act, 1947. The matter was in turn submitted to a small sub-committee, which has been continuing its work under Mr. Fitzgerald's chairmanship. During the last, eighteen months or so the Ministry of Transport says, this sub-committee has had many discussions with shops, offices and Government departments in the central area of London with a view to enlisting their co-operation in the staggering of working hours, and it is felt that there have been "useful results." But the problem has assumed fresh urgency in view of the extra traffic on public transport which petrol rationing will bring about. The most serious congestion of all, it has been stated, occurs between 5 p.m. and 6 p.m.

Rebuilding of Eindhoven Station

THE design of the new station of the Netherlands Railways at Eindhoven, which was officially opened in August, goes back to the beginning of 1953. Following the putting into service, in November, 1953, of the new high level railway line, the old installation was demolished in stages and work on the foundations of the station was begun. Construction of the piled foundations and the basement began in July, 1954, and was completed in May of the following year. In the meantime, orders had been placed with contractors for the main structure of the station building, and the various installations.

In the layout, full weight was given to considerations of town planning, both as regards organisation and as regards the architectural treatment. Organisationally, one seeks to arrange modern railway stations in such a way as to allow the travellers to change from one means of transport to another with the least delay possible. By the raising of the railway line, which at the same time was shifted to the north, parking space was gained for both public and private transport, including motor cycles and bicycles. Long-distance buses, local buses, taxis, and private cars are parked on separate areas in the forecourt to the south of the station, and motor cycles and bicycles are housed in the station basement.

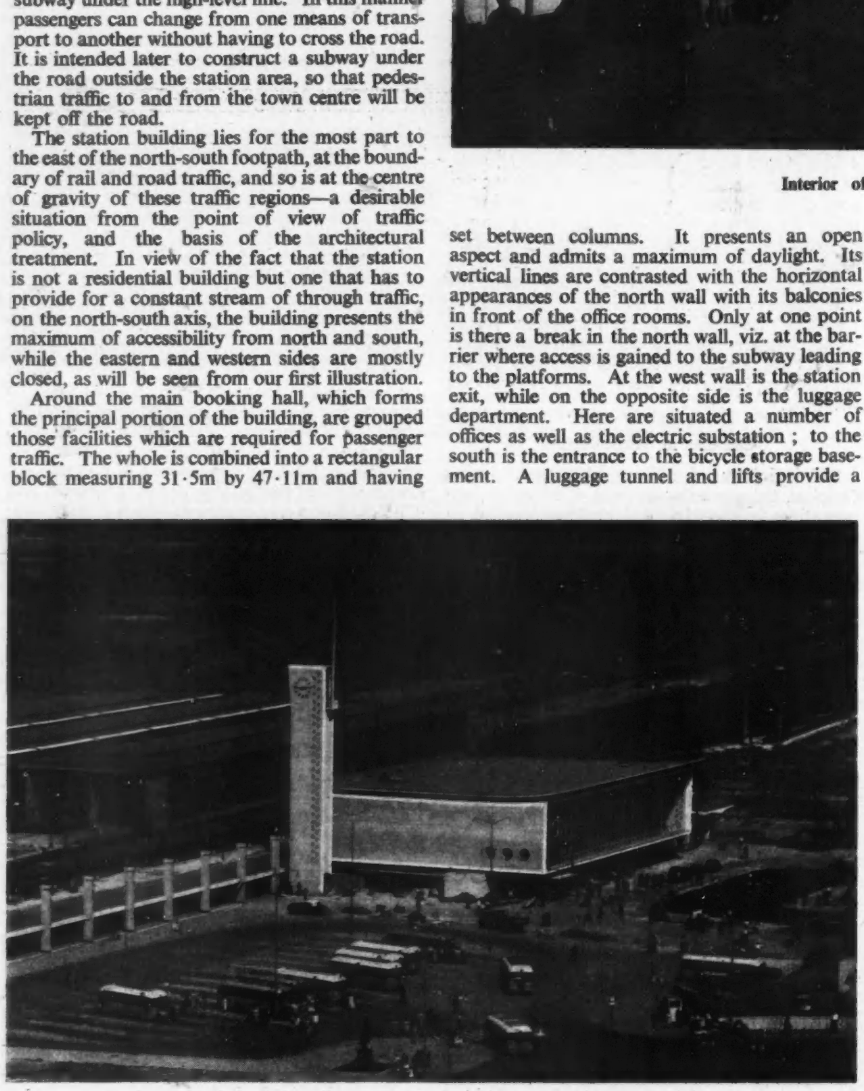
The pavements which surround the parking areas all merge into a single north-south pavement which lies in the direction of the pedestrian subway under the high-level line. In this manner passengers can change from one means of transport to another without having to cross the road. It is intended later to construct a subway under the road outside the station area, so that pedestrian traffic to and from the town centre will be kept off the road.

The station building lies for the most part to the east of the north-south footpath, at the boundary of rail and road traffic, and so is at the centre of gravity of these traffic regions—a desirable situation from the point of view of traffic policy, and the basis of the architectural treatment. In view of the fact that the station is not a residential building but one that has to provide for a constant stream of through traffic, on the north-south axis, the building presents the maximum of accessibility from north and south, while the eastern and western sides are mostly closed, as will be seen from our first illustration.

Around the main booking hall, which forms the principal portion of the building, are grouped those facilities which are required for passenger traffic. The whole is combined into a rectangular block measuring 31·5m by 47·11m and having an average height of 12m. At the southern side are the entrances, with a terrace above, while at the north side are the booking offices with two office floors above them. The main hall, which occupies the full height of the building, is divided at ground floor level into two portions by the newspaper kiosk and bookstall. The south wall is provided with clear glazing set between columns. It presents an open aspect and admits a maximum of daylight. Its vertical lines are contrasted with the horizontal appearances of the north wall with its balconies in front of the office rooms. Only at one point is there a break in the north wall, viz. at the barrier where access is gained to the subway leading to the platforms. At the west wall is the station exit, while on the opposite side is the luggage department. Here are situated a number of offices as well as the electric substation ; to the south is the entrance to the bicycle storage basement. A luggage tunnel and lifts provide a connection between the luggage office and the platform. The tunnel is also used by the adjacent post office.

Room has been provided in the basement for 1800 bicycles. It can be reached from the forecourt over a very gently sloping staircase equipped with cycle ramp. Travellers who have left their cycles can go directly upstairs to the booking hall by a normal staircase. In this part of the building is also housed the central heating plant—two oil-fired boilers—for the station building and the offices on the platforms. The combustion gases are removed through a chimney which is built into the 26m high tower.

Interior of the booking hall



The new station at Eindhoven seen from a south-westerly direction

As regards the structural problems involved in the building of the station, the use of piled foundations was rendered necessary by the poor and very variable subsoil. Piles 6m long were employed. The fact that the water table is higher than the basement level made it necessary to have a heavy foundation slab, 75cm thick, to prevent uplift.

The main structure is of reinforced concrete with a module of 4·20m. For the most part the frame is clad with yellow facing brick. Ample use has also been made of natural stone and decorative elements of precast concrete. Where it remains exposed to view, the concrete frame has been painted with three coats of chlorinated rubber paint.

The roof consists of precast concrete slabs, carried on reinforced concrete beams cast *in situ*. Aluminium frames of special section were used for the glazed south front. Entrance and exit doors also are of aluminium but with a steel centre. The offices at the back are of standard design, with a module of 1·40m, with non-load-bearing partitions, double-glazed window for heat insulation and protection from noise, ceilings of acoustic board, and fluorescent lighting.

Fluorescent lighting was used throughout the building with the exception of the restaurant terrace where incandescent bulbs are employed. Indirect fluorescent lighting is used in the main booking hall, the fittings being attached to the balustrade of the terrace in order to facilitate changing the tubes. Neon tubes are used in several places for signs, and on the hands and dials of the two large clocks, one on the tower and the other on the front of the building.

Heating is by hot water radiators, except on the terrace where a system of hot air circulation is used. In the ticket offices standard modern equipment is installed, i.e. horizontal ticket containers, turntables for issuing tickets and change, and "Hygieaphone" oval speaking panels. The timetables in the booking hall are mounted on rotatable cylinders.

Interior of the booking office

In the large space above the entrance to the passenger subway is placed a stained glass decoration designed by Mr. Lex Horn, showing various typical Dutch activities, such as fishing, dike construction, shipbuilding, &c. A kaleidoscope effect is obtained by mounting the glass between mirrors. At the other end of the hall, Mr. Horn has executed three similar panels depicting migratory birds.

On the western side of the main building is a relief in natural stone, by the sculptor Willy Mignot, showing in several panels the various stages in human life. Over the entrance and exit respectively, are the words "Ik kom" and "Ik ga" ("I come" and "I go").

Extensions at Dutch Shipyard

A double graving dock has been added to the facilities at the Wilton-Fijenoord shipyard at Schiedam. The double dock consists of two docks (Nos. 6 and 7), each 692ft 3in long by 103ft 4in wide at the bottom, with depths over keel blocks at high tide of 30ft 1in forward and 32ft 5in aft. While one of the new docks has the same length at the top, the other has a length at the top of 710ft. Both are suitable for ships up to 38,000 tons. The docks have solid floors, 24ft 8in thick, solid outer walls, and a hollow partition wall, which for the greater part is filled with earth. Between the partition wall and the floors a joint has been provided so as to allow for unequal settlement. In the longitudinal direction, too, joints have been provided, to the sealing of which careful attention has been given. As falling leaf gates, hinged at the bottom of the dock, demand great depth of water in front of the sill, which must be kept free from silt, and as silting in the harbour is considerable, it was decided to close the docks by means of floating steel caissons. These are 105ft high, 42ft 8in wide and about 9ft 10in thick, and are provided with floating, trimming and service tanks. The tanks are filled so that the doors exert a slight upward pressure against the hinges. Opening and closing is done by means of wire cables and capstans. When open, the doors are placed in recesses on either side of a continuation of the dock partition wall, which at the far end is protected against collisions by a heavy cylindrical jetty head consisting of steel sheet piles with earth filling topped by a slab of concrete.

At the end of the partition wall, nearest to the entrance, are the pump room and the equilibrium valves for filling and emptying the docks. Water enters under its own pressure through the inlet valves and passes into the dock through the eddying room, which extends across the width of the dock floor near the sill. For emptying, three electrically driven pumps are provided, each with a capacity of 2,200,000 gallons per hour against a 40ft head. These permit the dock, when flooded to average low tide level, containing about 14,3000,000 gallons, to be emptied in slightly over two hours. The pumps pump the water from a sump in the cellar to the outside through siphon tubes equipped with vacuum breaker valves; the installation of siphon tubes obviates the need for outlet valves to prevent backflow. As soon as the water level has dropped sufficiently the main pumps cut out automatically and the remainder of the water is removed by a combined bilge/ballast pump of 88,000 gallons per hour capacity at 115ft head. At very high tides or when inspection or repairs are to be carried out the inlet and outlet channels can be sealed by lowering a concrete trapdoor. The bilge pump is duplicated by another pump of the same capacity so that either pump can be used as bilge pump or for filling the double-bottom and cargo tanks which have to be pressure tested. In addition to these pumps there is a fire pump with a capacity of 30,800 gallons per hour at a discharge height of 328ft. This feeds the fire extinguishing installations which are fitted all round each dock, and a sprinkler pump with tank (26,400 gallons per hour at 328ft head), which can be connected to the fire extinguishing sprinkler system of a passenger ship. Ballast, fire and sprinkler pumps draw their water directly from the harbour, as the pump house inlet channel may be closed for repairs. In addition to the machinery described the pump house is equipped with pumps for high-pressure cooling water and priming, as well as two air compressors, air container and a vacuum tank. Above the pump floor is the electrical substation for 5000/380V, 50 c/s, a.c. and 110/220V d/c. A 440V, 60 c/s supply is to be installed shortly.

In each dock there have been installed four electric capstans of 7½ tons capacity with Ward-Leonard control, with provision for another two capstans to be added later.

Three portal cranes are provided, two of them jib cranes with capacities of 5 tons at 37m radius, 12 tons at 15m, and 18 tons at 41m, 40 tons at 20m, respectively. The third crane is a hammerhead crane with a capacity of 13·5 tons at 45m radius and 25 tons at 20m radius.

New Engine Works.—For some years past, the increased engine building programme had called for an expansion of facilities in this department. Because of restrictions imposed by the foundations and layout of the existing engine works, it was decided to build a complete new factory rather than extend the old one. On completion, the new plant will be used mainly for new building, while the old facilities will be devoted to repair work. The engine test bed, which is a post-war addition, will remain in the old factory, but will be used by both works.

The new factory occupies a floor area of 303ft 6in by 508ft 6in, divided into sections of equal and reasonably short lengths with a view to facilitating transport.

The structure is a steel frame with brick filling and glass fronts, covered with lightweight concrete slabs and provided with a number of skylights. Offices, washrooms, canteen and stores are arranged at the heads of the halls.

The width and height of the bays depends on the purpose for which they are used. Six of the bays are of single width and low or medium height, while two are of double width (83ft 6in) and 65ft 7in high. There is space between the two groups to provide a third large bay.

In view of the fact that pieces of up to 140 tons will be handled in the two large halls, substantial foundations had to be provided. These are prestressed and reach to a depth of over 20ft. They required about 5625 cubic yards of concrete and rest on 400 reinforced concrete piles, 65ft long. Travelling cranes from 7·5 to 75 tons capacity are installed.

The fact that the yard covered a large area made it desirable to carry out necessary extensions of office space by providing another office block in the eastern part of the work, in addition to the existing Office Building West. The "Dock Office East" building has three stories and comprises a stores wing and an administrative wing, the former also housing a canteen for 1000 employees.

The consulting engineer for the docks and buildings was the Architekten and Ingenieursbureau Ir. F. C. de Weger, Rotterdam. The contractors for the docks were N.V. Nederlandsche Beton Mij. Bato, The Hague, and for the factory, Bataafsche Annemings-Mij. v. h. Fa. J. van der Wal and Zn, The Hague.

Signing of Moselle Agreement

In conjunction with the signing of the Saar Treaty by the foreign ministers of France and Germany, which took place in Luxembourg on October 27, agreements were also signed regarding the Rhine Canal (Grand Canal d'Alsace) and the Moselle navigation. It is expected that the Moselle agreement will come into force at the same time as the Saar treaty, on January 1, 1957. About two years will then be required to complete the plans, before actual construction can begin.

To render the Moselle navigable has long been an object of French policy, as this would provide the Lorraine steel and iron industry with cheap coal and coke from the Ruhr. For the same reason the project has been strongly opposed by certain German interests, and the fact that an agreement in its favour has now been reached is an important political and economic event. The treaty provides that the Moselle should be made navigable between Koblenz and Thionville for barges up to 1500 tons. At the same time the water power of the river is to be utilised for generating electric power in such a way as may be determined by the partners to the agreement. On the German side an option has been obtained by RWE (Rheinisch-Westfälisches Elektrizitätswerk A.G.). The construction of the dam and power station, at Trierfeyen, is to be undertaken as soon as possible, independently of the remainder of the project.

An international Moselle company is to be formed in Trier with a capital of DM.102 million, of which France and Germany are to hold 50,000,000 each, and Luxembourg 2,000,000. The board is to consist of six members, two from each country, and the work is to be carried out by the existing national river authorities. Any dues will be applied to maintenance and improvements of the waterway, in the first instance, and only secondarily to the amortisation of the capital.

Of the total cost of the proposed navigation, amounting to an estimated DM.370 million, 248 million is to be provided by France, 120 million by Germany, and 2,000,000 by Luxembourg. The German contribution includes the sum to be provided by the RWE *à fond perdu*. Half the output of Grevenmacher power station (RWE) is to be supplied to Luxembourg at cost price.

Decrease in Rural Population

According to the Report on Agriculture published by O.E.E.C., the proportion of population living in rural areas is less than 50 per cent in most European countries. The figures are: Greece, 54 per cent; Spain, 49 per cent; Italy, 39 per cent; France, 32 per cent; West Germany, 23 per cent; Sweden, 18 per cent; Belgium, 12 per cent; and Great Britain, 6 per cent. In all countries the proportion of the rural population has decreased. The extent and tempo of the decrease were decisively influenced by the progress of industrialisation

Storage of Free Radicals at Low Temperature

BY OUR AMERICAN EDITOR

THE National Bureau of Standards has developed a technique for capturing and storing large numbers of highly reactive molecular fragments at temperatures near absolute zero. By this method, unstable atoms and free radicals, known to exist but momentarily in flames and hot gases, are produced in an electric discharge, frozen into immobility, and trapped in solid form. Because these atoms are frozen in the excited state, they can be conveniently studied by optical spectroscopy. In experiments to date the Bureau has produced solids containing atomic nitrogen and oxygen, and possibly atomic hydrogen and an unstable hydroxy (OH) molecule. These solids have very unusual properties, emitting bright glows, blue "flames," and coloured flashes of light. When warmed 20 deg. or 30 deg., they combine very actively, releasing large quantities of stored energy, principally as heat. Other possible fields of application include solid state physics and basic chemistry, where the "trapped" atoms could be used as probes into the solids containing them. These experiments were begun at the N.B.S. in 1954 and are being continued by the Bureau's temperature measurements laboratory. The research is supported chiefly by the Office of Naval Research and the U.S. Air Force through the Office of Scientific Research of the Air Research and Development Command.

Within the last five years, several methods have been developed in other laboratories for stabilising free radicals at low temperatures. However, the present technique has the advantage that the free radicals are stored in highly excited states as a result of the electric discharge, making it possible to study and analyse them by spectroscopic techniques. Also, since the radicals are collected at much lower temperatures than in previous methods, they can be stored longer in the uncombined form. In this method, gases containing molecules of nitrogen, hydrogen, oxygen, or water are first passed through a high-frequency electric discharge, then frozen very suddenly at 4·2 deg. Kelvin, just a few degrees above absolute zero. The apparatus developed at the Bureau is shown in Figs. 1 and 3. The discharge is maintained in a waveguide resonator by a 2450 Mc/s power supply. From the resonator, a glass tube leads the resulting molecular fragments into an evacuated metal vessel containing a cold window surface in contact with a liquid helium bath. To prevent solidification of the discharge products at temperatures above 4·2 deg. Kelvin, the gases are carried to the cold surface through a passageway that is kept near room temperature by contact with warm helium gas. When the gases reach the cold quartz window surface, they freeze into solid form there. Various techniques can then be used to study the resulting solids. Through windows in the metal vessel, a number of spectrographs of different designs can be aimed at the cold surface, and the light given off by the solids frozen on the surface can be analysed. To study the light absorbed by the solids, the gases are condensed on a transparent cold surface, and light is passed through the windows of the vessel, the condensed material, the cold surface and finally into the spectroscopes. To determine the heat evolved by the recombination of atoms, the gases are condensed into a small, simple, low-temperature calorimeter shown in Fig. 2, and the heat evolved by the material as it warms up is measured.

Because the free radicals produced by this method can be kept unchanged for many hours, a more detailed study of their properties has been possible than in previous work. For example, during the discharge through nitrogen the condensed solid emits a bright green glow, which tends to become yellow at high flow rates. The spectra obtained from this glow show that the structure of the solid condensed from the discharge differs from that of ordinary solid nitrogen. Each atom of the condensed nitrogen

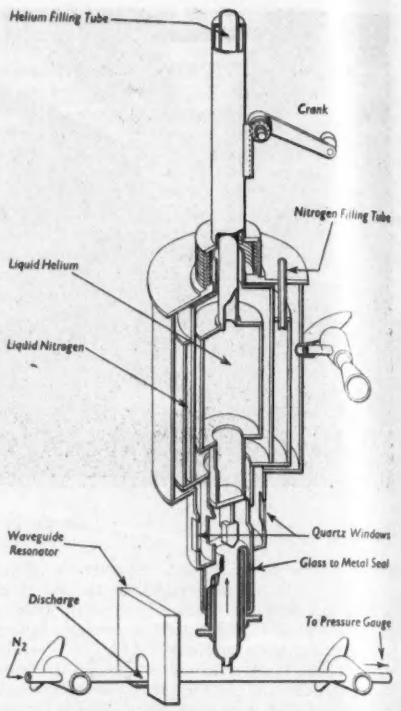


Fig. 3—Diagram of apparatus for the collection and spectroscopic observation of free radicals at low temperatures

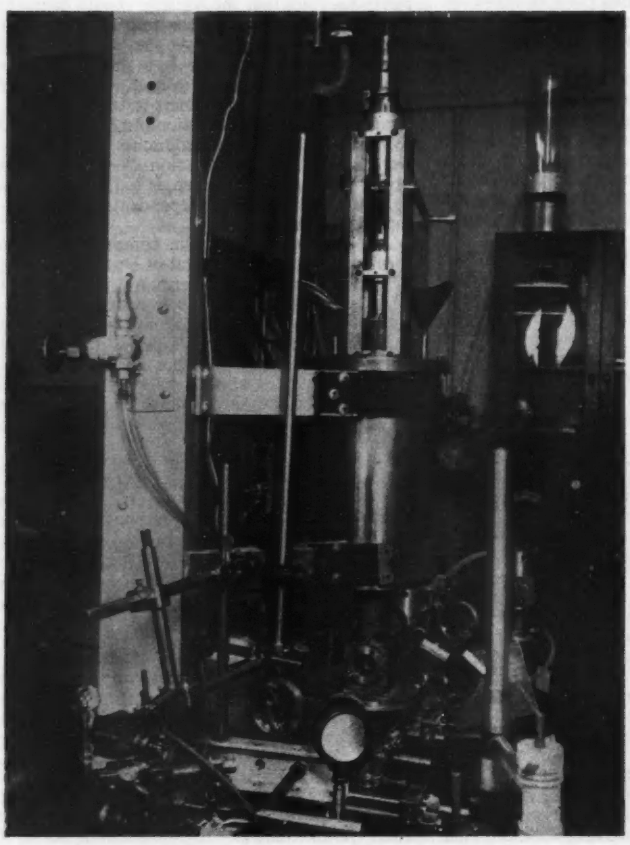


Fig. 1—Apparatus developed at the N.B.S. for the collection and spectroscopic observation of free radicals at low temperatures

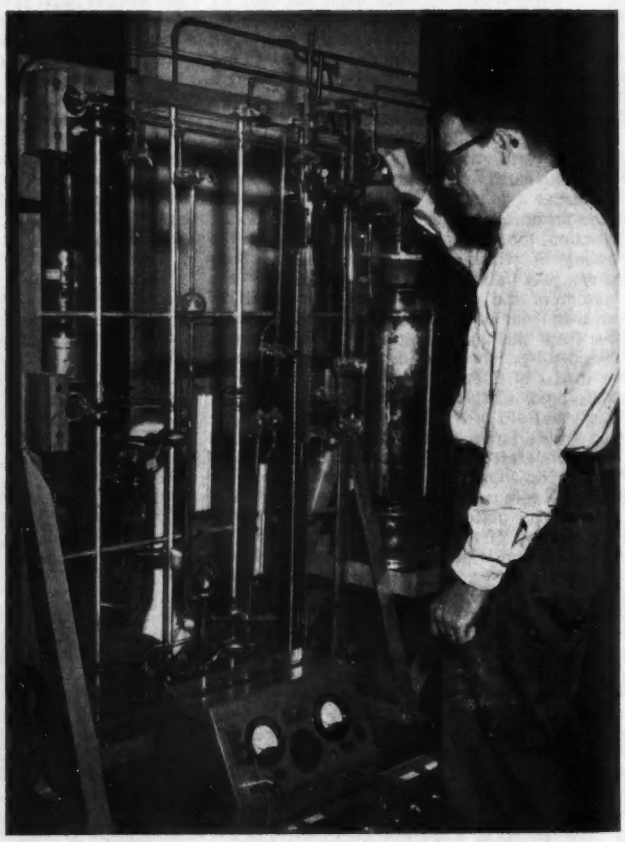


Fig. 2—Low-temperature calorimeter developed at the N.B.S. for determining the heat energy produced by the recombination of frozen free radicals

forms a very loosely bound complex with some neighbouring molecule and this complex has properties that differ from those of the separate atom and molecule. The evidence shows that the complex is a definite unit and by analysing its spectra the forces holding it together can be studied. Brilliant blue flashes are also observed from the solid surface during the nitrogen discharge. These flashes are thought to be due to local warming. After the flow of nitrogen is stopped, the discharge goes out and a green afterglow from the cold collected material persists for several minutes, decaying with a half life of about fifteen seconds. When the green afterglow has disappeared, a sudden warming of the vessel walls to between 25 deg. and 35 deg. Kelvin causes a blue "flame," which appears to "burn" through the condensed material. The light and heat thus given off are evidently due to the recombination of the atoms into molecules. When the light is analysed spectroscopically, it gives information about the structure of the molecule just formed and about the forces acting between two atoms. The reaction of a nitrogen atom with an oxygen atom can also be studied in this way.

When oxygen is passed through the discharge, a clear, glassy deposit is obtained which has rather complex absorption spectra. Upon warming this material to about 20 deg. Kelvin, the original deposit evaporates and a solid violet material condenses on the surface. This substance has been identified as a mixture of oxygen and ozone. Further warming of the violet substance produces ozone in large quantities. The initiation of chemical reactions in this way, by warming the frozen material, indicates the possibility of opening up a new field of very low-temperature chemistry, and because of the high chemical activity of the free radicals, new chemical compounds might be formed by this process. Low-temperature condensates have also been obtained from hydrogen and water. While the solids formed show complex behaviour similar to that of nitrogen and oxygen, the results are still incompletely understood.

Picture Transmission by the Bell Telephone System

THE Bell Telephone Laboratories, of New York, recently announced the development of a telephone that transmits pictures along with sound. Using an experimental "Picture-phone" set, as shown in Fig. 1, it has been possible to transmit recognisable pictures over short and long distances, even as far as from New York to Los Angeles. The experimental pictures vary in size from 1in by 1¼in to 2in by 3in, and are viewed from 1ft to 2ft away. Unlike television, a new picture is displayed every two seconds. It has good black-and-white contrast and the person at the other end of the line is recognisable. Head and shoulders can be seen and facial expressions are readily apparent.

The "Picture-phone" system is said to be the first system of its kind to use a pair of ordinary telephone wires, which gives it promise of being commercially feasible. Only one other line would be installed on the customer's premises to carry the picture. It will be possible for a caller's picture to be "dialled" like an ordinary telephone call, provided the switch on the picture equipment is turned on at both ends of the line. If the switches are off, the telephone call will be completed without pictures. The picture can also be turned on after a conversation is proceeding.

The operation of the Bell Telephone Laboratories "Picture-phone" system has been made possible by slowing down the rate of transmission of picture information to such an extent that the required bandwidth can easily be handled by conventional telephone circuits. The raster is made up of sixty lines, each of which may have a maximum of forty dots. Thus, each complete frame may be thought of as being made up of 2400 dots. If a single frame were transmitted each second, an overall bandwidth of 1200 c/s would be necessary. With the present system, one complete picture is transmitted every two seconds, requiring a bandwidth of 600 c/s. This 600 c/s "video" band contains very low frequency components which might suffer undue attenuation during transmission over telephone lines. Therefore, a carrier scheme is employed in which the "video" signal amplitude-modulates a 1200 c/s carrier. The transmitted intelligence is then a conventional amplitude-modulated double-side-band signal with a frequency range of 600 c/s to 1800 c/s. This signal lies within the range of optimum transmission of telephone lines and, therefore, can be treated exactly like a voice signal. It can be passed through repeaters and transmitted via microwave lines, coaxial cable and twisted pair or open wire lines.

Fig. 1—Experimental "Picture-phone" set for the telephone transmission of pictures and sound

An analysis of the system as a whole can best be made by referring to the block diagram reproduced in Fig. 2. This diagram outlines one possible assembly of components which has been tested experimentally. A conventional television camera of the design employed in industrial television systems is indicated. This camera contains a "Vidicon" tube and the necessary horizontal and vertical sweep circuits for producing a raster. These circuits are adjusted so that the sixty-line raster mentioned above is obtained, with one complete scan occurring every one-twentieth second. Since the transmitted picture repetition rate is only one every two seconds, a total of forty scans is available in the two-second interval. One of these scans is arbitrarily selected and the remaining thirty-nine are unused. The information in this scan is recorded on a magnetic drum which is rotating at a speed of 20 revolutions per second. All of the picture information for a single frame is thus recorded on a single rotation of the drum. By means of suitable gating and timing circuits, this stored information is then picked off the drum at one-fortieth the rate at which it was recorded. Thus, by the time it has turned forty revolutions during an interval of two seconds all the information from a single scan has been passed on to the modulator, and the drum is erased and made ready for the next picture. At this point, timing and synchronising data are combined with the signal to be transmitted. Such data are added in much the same manner as synchronising information is combined with a conventional television signal.

It is possible to take advantage of the storage properties of the camera tube itself, and thus eliminate the magnetic drum memory system. By means of a suitable shutter arrangement, the image tube can be made to receive a momentary image once every two seconds, and then the whole two seconds used for the scanning procedure. The signal thus derived can be sent directly to the modulator. Sufficient experience has been gained with this technique to indicate that it is feasible. Conventional modulating and demodulating techniques are employed in the system. At the receiver, the synchronising information is removed from the signal and used to control suitable horizontal and vertical sweep circuits. The remaining picture information is then presented to a suitable display medium which, in the case of the block diagram, is a pair of "Iatron" direct-view storage tubes.

The "Iatron" now being used is a recently developed commercially available electrostatic storage tube which uses electrostatic deflection. It has an inner screen just behind the fluorescent coating on which a picture may be stored by means of an electron gun and suitable scanning circuits. During this storing process, the face of the tube remains dark. Once the picture is stored, it may be made visible by means of a flood of electrons provided by a second electron gun. The picture will last for several minutes, if desired, and may be erased at will by applying a suitable potential to one of the electrodes. As can be seen from the block diagram, the present equipment employs two "Iatrons" placed at right angles to each other, with a half-silvered mirror placed as shown. Thus, the viewer can see the image on either of the tubes when the other one is dark. The technique employed is to write the information on one tube while the other is being viewed, and then to switch over so that a new picture is written on to the second tube while the first is being viewed. Each picture appears for two seconds.

An alternative receiving arrangement, which has been successfully tested at the Bell Laboratories is a combination of a magnetic drum storage system and an ordinary cathode-ray tube of small size. The drum memory system stores the incoming picture information, and then feeds it to the cathode-ray tube. Two magnetic drums are necessary so that one is storing information from the telephone line while the other is feeding information from the previous scan to the picture tube. This arrangement is essentially the reverse of the magnetic storage system employed in one version of the transmitter. Still another receiving system which is being investigated at the Bell Laboratories is the use of a facsimile recorder which prints the pictures on a small strip of paper, one every two seconds.

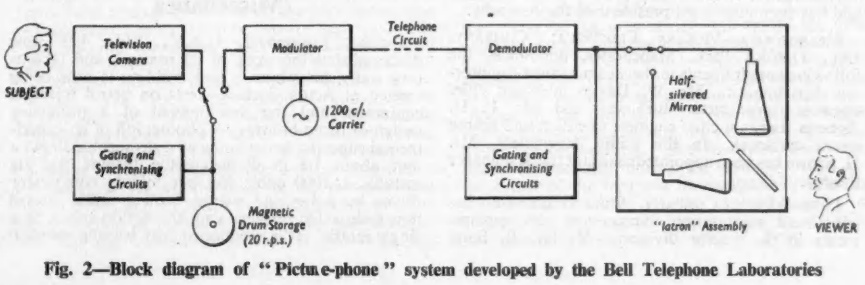


Fig. 2—Block diagram of "Picture-phone" system developed by the Bell Telephone Laboratories

Personal and Business

Appointments

MR. D. G. DODDS has been appointed chief industrial relations officer of the Central Electricity Authority.

MR. H. E. F. TAYLOR has been appointed executive secretary of the Radio Communication and Electronic Engineering Association.

MR. S. PARKER has been appointed applications engineer of Radiovisor Parent, Ltd., Stanhope Works, High Path, London, S.W.19.

BIRMINGHAM ALUMINIUM CASTING (1903), Ltd., Smethwick, Birmingham, has appointed Mr. R. V. Dowle as general works superintendent.

MR. E. J. SUTTON, M.I.E.E., has been appointed chief technical officer of the National Inspection Council for Electrical Installation Contracting.

DAWNAYS, Ltd., states that Mr. Alex. Ramsay has been appointed a local director (sales), and Mr. R. H. Wiles, local director (Welwyn Garden City).

MR. G. W. ALEXANDER, M.I.E.E., chief engineer of Powell Duffryn, Ltd., has been appointed a director of Cambrian Wagon and Engineering Company, Ltd., Maindy, Cardiff.

MASSEY-HARRIS-FERGUSON, Ltd., Toronto, announces the appointment of Mr. John H. Shiner as vice-president, marketing, and of Mr. Harold A. Wallace as vice-president, manufacturing.

MR. G. R. BUCKLEY, Mr. C. G. Mackie and Mr. C. H. Wilson have been appointed directors of Cochranes (Middlesbro') Foundry, Ltd. Mr. Wilson continues as general manager of the company.

MR. H. E. REYNOLDS, of Dobbie, McInnes, Ltd., has been elected president of the British Nautical Instrument Trade Association. Mr. A. J. Carter, Jun., of T. L. Ainsley, Ltd., has been elected vice president.

THE NATIONAL COAL BOARD has announced the appointment of Mr. W. H. Sales as chairman of the North Eastern Division in succession to Major-General Sir Noel Holmes, who is retiring at the end of January next.

MR. E. G. THOMPSON has been appointed technical sales manager of Baird and Tatlock (London), Ltd., Freshwater Road, Chadwell Heath, Essex. Mr. D. J. Wykes succeeds him as the company's public relations officer.

MR. J. F. PYM, A.M.I.E.E., has been appointed manager, overseas representatives and agencies, of the B.T.H. Export Company, Ltd. He succeeds Mr. C. W. Peyton, who has retired after forty-five years' service with the British Thomson-Houston Company, Ltd.

ARTHUR SCRIVENER, Ltd., Tyburn Road, Birmingham, announces the appointment of Mr. W. V. Hodgson as managing director. He succeeds Miss E. Harborne, who has relinquished the office for health reasons. Miss Harborne will continue to serve on the board.

THE STANTON IRONWORKS COMPANY, Ltd., near Nottingham, states that Mr. G. R. Buckley has been appointed assistant managing director (works), and Mr. C. G. Mackie, assistant managing director (commercial). Mr. N. C. Macdiarmid has been appointed assistant managing director (general).

CABLE AND WIRELESS, Ltd., announces the appointment of Mr. G. K. Nicholls as manager of the cable station and engineering school at Porthcurno, Cornwall. He succeeds Mr. C. J. V. Lawson, deputy engineer-in-chief, who will become engineer-in-chief on the retirement of Mr. J. A. Smale in March, 1957.

MR. I. HEY, M.I.Mech.E., has been appointed chairman, and Mr. Christopher Simon, deputy chairman, of Henry Simon (Holdings), Ltd., Cheadle Heath, Stockport. These appointments followed the resignation from the chairmanship of Lord Simon of Wythenshawe. Lord Simon continues as a director and has been appointed president of the company.

METROPOLITAN-VICKERS ELECTRICAL COMPANY, Ltd., Trafford Park, Manchester, announces the following appointments in the steam turbine engineering department: Mr. W. Davies, assistant chief engineer (large steam turbines), and Mr. F. D. Roberts, assistant chief engineer (medium and geared steam turbines). In the traffic department, Mr. H. Brown has been appointed assistant traffic manager (home).

FORD MOTOR COMPANY, Ltd., Dagenham, has announced organisation changes and new appointments in the tractor division. Mr. W. B. Batty continues as manager of the division, and Mr. M. MacDonald has been appointed sales manager. Departmental managers have been appointed as follows: Mr. H. W. H. James, domestic agricultural sales; Mr. E. J. Bullock, domestic industrial sales; Mr. R. D. Morton, export sales; Mr. A. M. Lasman, service department; Mr. G. A. Guthrie, mechanised farming centre. Mr. J. P. Higgins has become manager of the advertising and sales promotion department, and Mr. E. B. Black has been appointed manager of the public relations department, in succession to Mr. J. H. Deeley, who is leaving the company. Mr. W. A. Pollitt has been appointed acting manager of the product planning department.

Business Announcements

MR. E. K. COLE, chairman and managing director of E. K. Cole, Ltd., has left this country for a visit to Australia.

RICHARD KLINGER, Ltd., Sidcup, states that its Midland office has been moved to Court Buildings, 662, Warwick Road, Solihull (telephone, Solihull 4675).

ROCKWELL MACHINE TOOL COMPANY, Ltd., Welsh Harp, Edgware Road, London, N.W.2, is now the sole agent in the United Kingdom for McKay Machine Company, Youngstown, Ohio.

THE CENTRAL ELECTRICITY AUTHORITY states that Mr. F. W. Smith, chief contracts officer, is retiring at the end of this month. He will continue thereafter to act, on a part-time basis, as contracts adviser.

MR. PHILIP H. SUGG is retiring from the board of William Sugg and Co., Ltd., after fifty-four years in the service of the firm, which was founded by his grandfather 119 years ago. Mr. Sugg was chairman of the company from 1921 till 1954.

BRITISH INSULATED CALLENDER'S CABLES, Ltd., states that its branch office at Tunbridge Wells has been transferred to Water Lane, Maidstone (telephone, Maidstone 51113). The telephone number of the company's Swansea office is now Swansea 52094.

ANGLO GREAT LAKES CORPORATION, Ltd., is the name of a British company which is being established for producing nuclear-quality graphite. This company is being formed jointly by C. A. Parsons and Co., Ltd., A. Reyrolle and Co., Ltd., Sir Robert McAlpine and Sons, Ltd., and Clarke, Chapman and Co., Ltd., in collaboration with the Great Lakes Carbon Corporation of New York. The new company is to construct a factory on Tyneside, work on which is expected to begin early in the New Year.

Contracts

THE ENGLISH ELECTRIC COMPANY, Ltd., has received from Rhodesia Railways an order for a further twelve 2000 h.p. diesel-electric locomotives.

MATTHEW HALL AND CO., Ltd., has been awarded the design and procurement contract, as a sub-contractor of Blaw-Knox Company, of Pittsburgh, U.S.A., for a synthetic rubber plant near Fawley, for the International Synthetic Rubber Company. The total cost of this part of the plant is expected to be in the region of £4,000,000.

RUSSELL CONSTRUCTION, Ltd., of Toronto, a wholly-owned subsidiary company of Balfour, Beatty and Co., Ltd., London, has been awarded a contract, valued at £2,570,000, by the St. Lawrence Seaway Authority, in connection with dredging in the Welland Ship Canal, which joins Lake Erie and Lake Ontario. The contract consists of drilling and blasting rock to deepen the canal in preparation for the larger ships passing through when the Seaway is complete. All work has to be carried out in such a way as not to interfere with normal shipping, and the contract is due for completion by September 30, 1958.

Miscellanea

ENGINE EQUIPMENT.—C.A.V., Ltd., has now disclosed that the work of its research and laboratory staffs, for whom a new building is now being erected at Acton, includes tests on petrol injection equipment and the development of a promising design of turbo-blower. A photograph of an experimental supercharger running as a gas turbine shows a unit about 1ft in diameter—the turbine test rig includes a 1000 cubic feet per minute compressor driven by a Leyland engine—with a radial inward flow turbine fed through a square section volute by a single intake. It is mentioned that bearing research has involved speeds of 50,000 r.p.m. Another photograph of the diesel laboratory shows a four cylinder B.M.C. engine running with a distributor fuel pump.

MACHINE TOOL MANUFACTURERS' EXHIBITION.—An exhibition of machine tools made by the Kerry group of companies is to be held at the new depot opened by Kerry's (Great Britain), Ltd., at 41–42, Bromsgrove Street, Birmingham, 5, from December 11 to 13. The display will include the complete range of Kerry drilling machines and lathes, Qualters and Smith hacksawing machines, and some Broadbent lathes, in addition to a selection of machines distributed by the firm. Many of these machines will be in operation, and demonstrations will be given throughout the exhibition.

GRAPHITE HEAT EXCHANGERS.—A new series of graphite block heat exchangers having larger heat transfer areas and tube diameters than hitherto, has been introduced by Powell Duffryn Carbon Products, Ltd., Springfield Road, Hayes, Middlesex. The new exchangers are made in three standard models with effective surface areas of 100, 150 and 200 square feet and tube or hole diameters of ⅜in. Their design is basically that of the patented "Delanium" cubic heat exchanger except that the dimensions of the graphite block have been extended and the flow patterns modified to suit the altered shape of the block. Multiple pass arrangements of up to sixteen passes on either side of a block are available to suit the flow rates of both liquors and to ensure minimum pressure drop.

"TRANSPORT TREASURES" EXHIBITION.—Another historical exhibition, entitled "Transport Treasures," has been prepared by the British Transport Commission and is now open in the Shareholders' Meeting Room at Euston Station. The exhibition is to remain open indefinitely and in it there are displayed miscellaneous items from the Commission's collection of smaller relics illustrating various types of public transport and their histories. A series of models includes the locomotive "Wildfire" built by Robert Stephenson in 1837 for the Grand Junction Railway; the paddle steamer "Mary Beatrice," which was engaged on the cross-channel service between Folkestone and Boulogne in 1882, and Shillibeer's first London omnibus of 1829.

MACHINE CLAMP.—A new machine clamp supplied by the Headland Engineering Developments, Ltd., 164, Westminster Bridge Road, London, S.E.1, is designed to hold a workpiece of any shape or size on a machine table, whilst leaving the surface of the work entirely free of obstruction. The clamp has a base of cast steel and its head, which is carried on a 2in diameter threaded shank, has the jaw faces hardened and ground. The shaft carrying the headpiece is inclined in the base at an angle of 5 deg. and when the clamp is screwed downwards this angle causes the jaws to approach the work slowly in an inwards and downwards direction to lock it rigidly on the machine bed. The jaws can be rotated when setting the clamp to enable a workpiece to be held on the most suitable face or faces.

JUTE HESSIAN WRAPPINGS FOR STEEL.—Jute hessian treated to protect bright steel parts against corrosion and rusting is now in commercial production, following research work undertaken in the laboratories of the British Jute Trade Research Association. The impregnated hessian, used as a wrapping for bright steel strips and bars, is stated to give full protection under all humid and acidic atmospheric conditions likely to be encountered in transit and storage. It is being supplied in varying widths and on rolls with cardboard centres for reeling off quickly in the wrapping operation. For use with high-speed wrapping machines, the hessian can be supplied with a dustproof treatment. The anti-corrosive treatment is also effective where jute bagging is employed for carrying bright steel products.

CAREERS FOR ENGINEERS IN RAILWAY SERVICE.—The British Transport Commission has just issued a new publication entitled "Careers with a Future for Mechanical and Electrical Engineers." This book is designed to provide detailed information for potential engineers, appointments officers, careers masters and others who may be interested in the engineering training and prospects available in the railway service. It outlines a group of engineering training courses planned by British Railways for trainees entering a service which has an important future and which, because of the great variety of railway engineering work, can provide a training claimed to be unequalled in its scope. The book includes charts showing all the lines of possible promotion in British Railways' electrical and mechanical engineering departments, and examples of the various courses open to young engineers.

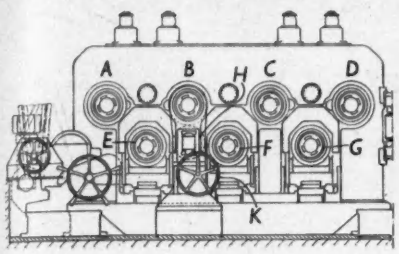
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

MACHINE TOOLS

760,582. July 29, 1953.—ACCESSORY APPARATUS FOR ROLLER STRAIGHTENING MACHINES, Werner Muller and Kurt Schafhausen, responsible partners of the firm Maschinen-Und Bohrgeratefabrik Alfred Wirth and Co. K. G., of Erkelenz/Rheinland, Germany.

It is known that in roller straightening or levelling machines for straightening rails or other section members, the rails which are straightened have a somewhat greater thickness or height at their two ends than over the rest of their length. The object of the invention is to remove this difference. The



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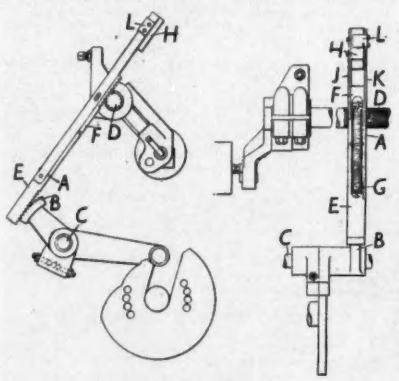
drawing shows a roller straightening machine of normal construction with rollers *A*, *B*, *C*, *D* and *E*, *F*, *G* which are staggered relatively to one another. The differences in height occur because the section member to be straightened is acted on only on one side by the roller *A* on entering the straightening machine and by the roller *D* on leaving the machine. Compensation is effected by the accessory device which in the drawing is so formed that an auxiliary roller *H* is arranged to operate in association with the straightening roller *B*. It is necessary only to make the distance of the roller *H* from the roller *B* such that as the section passes through the machine the inaccuracies are removed. If an auxiliary roller is arranged to operate in association with a straightening roller which is already present, it is only necessary to supply the auxiliary roller together with its adjusting device. The adjusting device comprises a base and an adjusting wheel *K*, installed together with the separate auxiliary roller.—*November* 7, 1956.

760,821. December 31, 1953.—SAFETY DEVICES FOR STOPPING MACHINERY WHEN OBSTRUCTION OCCURS, Brown and Ward (Tools), Ltd., Hatherton Lane, Leamore, Walsall, Staffordshire. (*Inventor: Frederick William Kendall.*)

The invention relates to safety devices for stopping the power drive to machinery in the event of obstruction of the type in which movement takes place between two parts against spring pressure when the load transmitted between the two parts is increased beyond a predetermined limit to disconnect the



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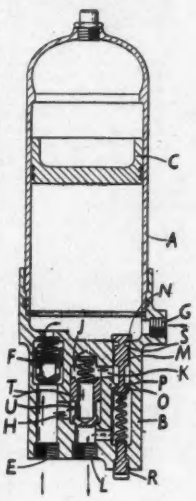
power drive. As will be seen from the drawing arrangement, a rack bar *A* transmits movement from a cam actuated toothed sector *B* on a spindle *C* to a shaft *D* of an automatic machine, power being transmitted in that direction of movement in which the rack bar acts in tension. The rack bar is made in two parts *E* and *F* slidably mounted together, so that the bar can extend. The two parts are held together against power transmitted by the rack bar by a tension spring *G*. A limit switch *H* is mounted on a bar *J* on one part *F* and a bar *K* carrying a switch operating plate *L* is mounted on the other part *E*. Should the rack parts pull apart, as illustrated, the pressure plate presses on the button of the switch to stop an electric motor driving the machine. The parts *E* and *F* of the rack are slidably held together and a limited movement is provided between the normal working position and the switch engaging position. Should a mechanical failure in the operation of the machine or an obstruction occur in the machine, the power will be cut off and damage prevented.—*November* 7, 1956.

HYDRAULIC MACHINERY

760,010. May 19, 1953.—AUTOMATIC CUT-OUTS FOR HYDRAULIC CIRCUITS, British Messier, Ltd., Cheltenham Road, Gloucester. (*Inventors: Frank Desmond Taylor and John Linnell Fyleman.*)

According to the invention, a hydraulic system having a pump, a cut-out for the pump and an accumulator, is characterised by the fact that the accumulator and cut-outs are combined into one unit located within an end fitting for closing the accumulator, so that there is no appreciable pressure difference between the accumulator pressure and the operating pressure in the cut-out. The drawing shows a section through a combined accumulator and cut-out in accordance with the invention. An accumulator chamber *A* is hemispherical at one end and open at the other. The open end is closed by a fitting *B* which contains an automatic cut-out. This accumulator is of the usual type containing a floating piston *C* to separate air at the hemispherical end from hydraulic fluid. The hemispherical end is provided with an air filling valve. The cut-out fitting has an inlet port *E* at the bottom leading to a non-return lift valve *F* and thence into the accumulator chamber. From the chamber there is an outlet port *G* to the hydraulic circuit to be supplied. Between the inlet port and the non-return valve is a branch *H*



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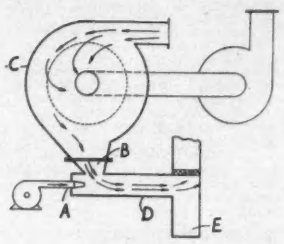
leading through a cylindrical by-pass chamber *J* to one end of a pilot conduit *K*. The other end of the pilot conduit opens into a chamber, the ends of which are connected, respectively, to the accumulator chamber and a port *L* connected to the exhaust tank. A two-way pilot valve *M* extends through this chamber and has a head *N* seating on the opening to the accumulator and another head *O* at the other end seating on a port *P* connected to the exhaust port *L*. A spring keeps the port *P* normally closed, and the port to the accumulator open. The centre part *S* of the pilot valve nearly fills the chamber in which it is located. The cylindrical by-pass chamber *J* has a seating leading to the exhaust port *L*. A cylindrical main by-pass valve *T* fits the chamber and a reduced conical portion at the end closes the seating. The branch *H* from the normal flow conduit enters this chamber below the body of the valve and above the seating so that the pressure tends to lift the by-pass valve. The valve is made hollow and has a bleed hole *U* in the side which passes pressure fluid to the interior and then on to the pilot conduit *K*. In operation, the pump delivers through the non-return valve *F* to the accumulator and builds up pressure therein. Pressure has access to the pilot valve both on the head *N* in the accumulator and through the bleed hole *U*. As this pressure will fill the chamber above the by-pass valve *T*, it holds the latter closed. When the pressure becomes sufficient to overcome its spring, it moves the pilot valve *M* to open the exhaust port *P*. Due to the double-headed construction of this valve and to the restricted passage for fluid between the centre part of the pilot valve and the pilot conduit, the pilot valve tends to flick over rapidly from the first (or upper) position to the second (or lower). This opens the upper part of the by-pass chamber *J*, above the by-pass valve *T*, to exhaust and the pressure in the annulus of the by-pass valve below the cylindrical body, lifts it and opens the by-pass exhaust port. As soon as pressure falls to a point where its spring can close the pilot valve *M*, the parts return to their first position. The setting of the cut-out pressure is obtained by varying the load on the two-way pilot valve spring, and the ratio of cut-out to cut-in pressure is a function of the ratio of the valve seat areas of the top and bottom valve-heads *N* and *O* on the pilot-valve *M* and of the rate of the pilot spring.—*October* 31, 1956.

SCREENS AND SEPARATORS

760,046. February 23, 1954.—DUST AND LIKE SEPARATORS, Vokes, Ltd., Henley Park, Guildford, Surrey. (*Inventor: Noel Reginald Fortescue Mortimer.*)

The invention relates to separators for dust or other particles in which the particles are separated from a stream of air at less than atmospheric pressure. The separator may be of the cyclone or rotary screen type. In a preferred form of apparatus according to the invention shown in the diagrammatic drawing, the ejector *A* discharges across the outlet passage *B*



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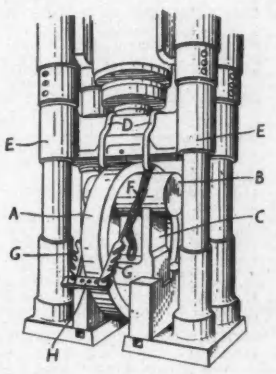
from the separator *C* (of the rotary screen type) and is aligned with an outlet duct *D* for the particles. A vertical box *E* at the end of the outlet duct has a vertical wall against which the particles impinge and then fall out of the air stream. The ejector induces a small flow of air from the separator into the particle outlet duct and this air, together with that operating the ejector, may be collected from the top of the box after passing through a filter, which prevents dust arising at the outlet. The particle discharge apparatus has no moving parts and it is particularly suitable for use with leaf material, especially when in a moist condition.—*October* 31, 1956.

METALLURGY

760,286. August 20, 1954.—FORGING PRESSES FOR RING-LIKE OBJECTS, "Veb" Leuna-Werke "Walter Ulbright," Leuna, near Merseburg, Germany. (*Inventor: Karl Lichtenfeld.*)

The invention concerns forging presses for forging annular parts, such as tyres, flanges or pipe bases, in which an essential operation is the turning of the ring progressively through a certain angle after each stroke of the press. As shown in the drawing, the ring *A* to be forged is placed on the supporting mandrel *B*, which is held by the "U"-shaped



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support *C*. Hooks are fixed to the movable press-crosshead *D* and a clamp is suspended on the hooks by chains *F*. The clamp consists of two side parts *G*, connected together by means of a strap *H*. The chains are of a length to form an angle of about 20 deg. to 30 deg. to the vertical. The distance between the two side-straps *G* is such that when the chains are pulled the ring is gripped by its two faces and pulled with them. When the crosshead descends in the course of the press-stroke, the chains are loose and the clamp, with the cross-strap *H*, slides down over the ring. The effective length of the clamp is adjustable, for example, by the pin and slot coupling, as shown. As the progressive turning of the ring is effected by the turning device, the operator merely has to ensure that the ring rests on the cross beam in the correct position. The feed-movement takes place automatically during the upward stroke and the extent of the feed can be regulated by selecting appropriate distances for the upward strokes, or adjustable linkages can be used to allow for variation in the angular distance.—*October* 31, 1956.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Dec. 7.—LIVERPOOL BRANCH: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "Modern Short-Circuiting Testing Technique," J. G. P. Anderson, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Wed., Dec. 12.—LONDON SECTION: School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Principles of the Light Amplifier and Allied Devices," T. B. Tomlinson, 6.30 p.m.

Thurs., Dec. 13.—MERSEYSIDE SECTION: Chamber of Commerce, 1, Old Hall Street, Liverpool, 3, "An Automatic System for Electronic Component Assembly," K. M. McKee, 7 p.m.——SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Design and Manufacture of Modern Capacitors," J. H. Cozens, 7 p.m.

Fri., Dec. 14.—S. MIDLANDS SECTION: Technical College, Cheltenham, "Radio Astronomy," R. L. Adgie, 7 p.m.

CHEMICAL SOCIETY

Thurs., Dec. 13.—TILDEN LECTURE: Royal Institution, Albemarle Street, London, W.1, "Physical Properties of High Polymers in Relation to their Chemical Structures," G. Gee, 7.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., Dec. 12.—MIDLAND SECTION: Queen's Hotel, Birmingham, "The Place of the Gas Turbine in the Combined Heat and Power Generating Plant," J. R. Needham, 10.30 a.m.

ILLUMINATING ENGINEERING SOCIETY

Mon., Dec. 10.—LEEDS CENTRE: E.L.M.A. Lighting Service Bureau, 24, Aire Street, Leeds, "The Electrical Installation of the New Leeds College of Technology," J. H. Gura, 6.15 p.m.——SHEFFIELD CENTRE: The University, Western Bank, Sheffield, Presidential Address, W. E. Harper, 6.30 p.m.

Tues., Dec. 11.—LONDON CENTRE: Federation of British Industries, 21, Tothill Street, London, S.W.1, "Automobile Headlamps: The ISO/CIE International Tests and their Influence on Meeting Beam Design," J. H. Nelson, 6 p.m.

INCORPORATED PLANT ENGINEERS

To-day, Dec. 7.—PETERBOROUGH BRANCH: White Lion Hotel, Church Street, Peterborough, "Control of Loads on the Grid," 7.30 p.m.

Mon., Dec. 10.—DUNDEE BRANCH: Mathers Hotel, Dundee, "Combustion," film and discussion, 7.30 p.m.——GLASGOW BRANCH: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "The Plant Engineer's Approach to Materials Handling," 7.15 p.m.

Tues., Dec. 11.—MANCHESTER BRANCH: Textile Institute, Blackfriars, Manchester, "Management of Men," The Right Rev. the Lord Bishop of Manchester, 7.15 p.m.——S. WALES BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, Ten-Minute Talks and Discussion, 7.15 p.m.

Wed., Dec. 12.—WESTERN BRANCH: Grand Hotel, Bristol, "Combustion and Steam Raising," D. C. Gunn, 7.15 p.m.

Thurs., Dec. 13.—MERSEYSIDE AND N. WALES BRANCH: Exchange Hotel, Liverpool, "Bearings and Bearing Failures," R. W. Jones, 7.15 p.m.——N.E. BRANCH: Roadway House, Oxford Street, Newcastle upon Tyne, Open Discussion, 7 p.m.

Fri., Dec. 14.—BIRMINGHAM BRANCH: Imperial Hotel, Temple Street, Birmingham, Mobile Plant Discussion Group, "British Tractors," 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sat., Dec. 8.—LANCASHIRE BRANCH: Midland Hotel, Manchester, "Cupola Experiments," K. G. Harris, 3 p.m.——NEWCASTLE BRANCH: Neville Hall, Westgate Road, Newcastle upon Tyne, "Latest Developments in Spheroidal-Graphite Iron," W. W. Braidwood, 6 p.m.——SCOTTISH BRANCH: Royal Technical College, George Street, Glasgow, Discussion on Foundry Problems, 3 p.m.——WALES AND MONMOUTH BRANCH: S. Wales Institute of Engineers, Park Place, Cardiff, "CO_2 Process," G. E. Parramore, 6 p.m.——W. RIDING OF YORKS BRANCH: Technical College, Bradford, "Use of Exothermic Compounds," G. N. Cherry, 6.30 p.m.

Wed., Dec. 12.—BIRMINGHAM BRANCH: Grand Hotel, Birmingham, Reading of papers entered for the Student Prize Short Papers Competition, 7.15 p.m.

Thurs., Dec. 13.—LINCOLNSHIRE BRANCH: Technical College, Lincoln, "Dust Control," R. D. Lawrie, 7.15 p.m.——BEDS AND HERTS SECTION: K. and L. Steelfounders and Engineers, Ltd., Letchworth, "Experiences of Forty Years In and Around Foundries," W. Hardy, 7.30 p.m.

Fri., Dec. 14.—TEES-SIDE BRANCH: Teesdale Hall, Head Wrightson and Co., Ltd., Thornaby-on-Tees, "Some Notes on Foundries," Charles Wilson, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Dec. 11.—85, Minories, London, E.C.3, "Some Aspects of the Application of Planned Maintenance to Marine Engineering," W. H. Falconer, 5.30 p.m.

Wed., Dec. 12.—JUNIOR LECTURE: Municipal College, Southend-on-Sea, "Gas Turbines," R. D. Teire, 7.30 p.m.——SOUTHERN JOINT BRANCH: College of Technology, Portsmouth, "Free-Piston Engines," F. A. I. Muntz and P. Watson, 7.30 p.m.——MERSEYSIDE AND N.W. SECTION: Riversdale Technical College, Liverpool, "The Construction of the Ship," G. Ridley Watson, 5.30 p.m.——SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Reheating as a Contribution to the Economy of the Marine Steam Turbine, with special reference to the Installation in T.S.S. 'Empress of Britain,'" A. W. Davis, 7.30 p.m.

Thurs., Dec. 13.—KINGSTON UPON HULL AND E. MIDLANDS SECTION: Royal Station Hotel, Kingston upon Hull, "Marine Lubrication," G. H. Clark, 7.30 p.m.——W. MIDLANDS SECTION: Exchange and Engineering Centre, Stephenson Place, Birmingham, "The Application of Planned Maintenance to Marine Engines," W. H. Falconer, 7 p.m.

INSTITUTE OF METALS

Mon., Dec. 10.—SCOTTISH LOCAL SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Metal Quality Tests for Copper-Base Alloys," A. R. French, 6.30 p.m.

Tues., Dec. 11.—S. WALES LOCAL SECTION: University College, Singleton Park, Swansea, "Recent Developments in Aluminium Alloys and their Uses," J. C. Bailey, 6.45 p.m.

INSTITUTE OF NAVIGATION

Fri., Dec. 14.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Port Operation in Fog," L. S. le Page, W. R. Colbeck and R. F. Hansford, 5.15 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Mon., Dec. 10.—E. REGIONAL CENTRE: Council Chamber, Houldsworth Hall, 90, Deansgate, Manchester, "The Application of Electric Power to Passenger and Goods Road Transport," T. P. O'Donnell, 7.30 p.m.

Tues., Dec. 11.—MIDLANDS CENTRE: Exchange and Engineering Centre, Stephenson Place, Birmingham, "The Development and Operation of Disc Brakes," T. J. Phipps, 7.30 p.m.

Thurs., Dec. 13.—W. REGIONAL CENTRE: Adelphi Hotel, Lime Street, Liverpool, "The Place of Aircraft in the Transport Field," C. B. Bailey-Watson, 7.30 p.m.

Fri., Dec. 14.—S. WALES GROUP: S. Wales Institute of Engineers, Park Place, Cardiff, "Current Trends in Fuel Injection Equipment for Road Transport," J. Skinner, 7 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Mon., Dec. 10.—NORTHERN CENTRE: N.E. Electricity Board's Lecture Theatre, Carliol House, Newcastle, "Baling for Silage," R. M. Chambers, 6.45 p.m.

Tues., Dec. 11.—6, Buckingham Gate, London, S.W.1, "Tillage Equipment and Soil Conservation," W. H. Cashmore and J. C. Hawkins, 5.30 p.m.——WESTERN CENTRE: Lackham School of Agriculture, Chippenham, "Down the Row Thinning," G. L. Maughan, 7.15 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

Wed., Dec. 12.—MIDLANDS BRANCH: Midlands Institute, Paradise Street, Birmingham, "Heat Transfer and Pressure Drop in Packed Beds," F. H. Garner, C. W. Nutt and C. A. le Merle, 6.30 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Dec. 11.—AIRPORT MEETING: Great George Street, Westminster, London, S.W.1, Symposium on Stabilized Soil Runways, General Reporter, D. J. Maclean; "The Construction of a Soil Cement Runway at Christchurch, Hants," R. A. Foulkes; "Soil Stabilized Pavements at Southend-on-Sea Municipal Airport," T. B. Hill and K. H. G. Williams; "A Heavy-Duty Airfield Pavement Embodying Soil Stabilization," F. R. Martin, 5.30 p.m.

Wed., Dec. 12.—MIDLANDS ASSOCIATION: Midland Institute, Paradise Street, Birmingham, "The Kitimat Story," film and lecture, F. L. Lawton, 6.30 p.m.——N.W. ASSOCIATION: County Hall, Preston, "Skidding Resistance of Roads and the Requirements of Modern Traffic," C. G. Giles, 6.15 p.m.

Thurs., Dec. 13.—CONSERVATION OF NATURAL RESOURCES: Great George Street, Westminster, London, S.W.1, "The Use of Waste Materials," R. M. Finch, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., Dec. 10.—INFORMAL MEETING: Savoy Place, London, W.C.2, Discussion on "Unsolved Problems Arising from Automation," opened by G. L. E. Metz, 5.30 p.m.

Wed., Dec. 12.—RADIO AND TELECOMMUNICATION SECTION: Savoy Place, London, W.C.2, "The B.B.C. Sound Broadcasting Service on Very-High Frequencies," E. W. Hayes and H. Page, 5.30 p.m.

Thurs., Dec. 13.—UTILIZATION SECTION: Savoy Place, London, W.C.2, Discussion on "The Thirteenth Edition of the Wiring Regulations," opened by Forbes Jackson, 5.30 p.m.

Fri., Dec. 14.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "The Teaching of the Fundamentals of Transistor Circuits to Students of Electrical Engineering," opened by P. Godfrey, 6 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Mon., Dec. 10.—Northern Architectural Association Hall, 6, Higham Place, Newcastle upon Tyne, "The Design of a High-Speed Cine Camera for Industrial Research," F. A. Roberts, 7.15 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Fri., Dec. 14.—JOINT MEETING: Robert Gordon's Technical College, Aberdeen, "Experiences with Welded Hulls," J. Turnbull, 7.45 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Dec. 7.—GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, "The Self-Excited Vibration of Axial-Flow Compressor Blades," A. D. S. Carter, 5.30 p.m.——N.W. BRANCH: Central College of Further Education, Barrow-in-Furness, "Fretting Corrosion," R. B. Waterhouse, 7.30 p.m.

Sat., Dec. 8.—LONDON GRADUATES' SECTION: Visit to the National Physical Laboratory, Teddington, 2 p.m.

Mon., Dec. 10.—SCOTTISH GRADUATES' SECTION: 25, Charlotte Square, Edinburgh, "Development of the Racing Car," W. R. Flockhart, 7.30 p.m.

Tues., Dec. 11.—AUTOMOBILE DIVISION, GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, "Rubber Springs for Vehicle Suspension," A. E. Moulton and P. W. Turner, 6 p.m.

Wed., Dec. 12.—STEAM GROUP DISCUSSION: 1, Birdcage Walk, Westminster, London, S.W.1, "The Draft Code of Practice for Acceptance Tests on Steam Turbine Installations," 6.45 p.m.

Thurs., Dec. 13.—YORKSHIRE BRANCH: Chemistry Lecture Theatre, The University, Leeds, "Fuel Control and Burning in Aero-Gas-Turbine Engines," E. A. Watson, 6.30 p.m.——E. MIDLANDS GRADUATES' SECTION: College of Technology, Leicester, "Medium Scale Production of Sintered Carbide Tools," S. K. Maini, 7.15 p.m.——LONDON GRADUATES' SECTION: 1, Birdcage Walk, Westminster, London, S.W.1, "The Effect of Spirit Quality on Vehicle Performance," J. Tubman, 6.30 p.m.

Fri., Dec. 14.—GENERAL MEETING: 1, Birdcage Walk, Westminster, London, S.W.1, James Clayton Lecture, "Mechanical Breathing Machines," G. T. Smith-Clarke, 6 p.m.

INSTITUTION OF NAVAL ARCHITECTS

Wed., Dec. 12.—SOUTHERN JOINT BRANCH: College of Technology, Portsmouth, "Free-Piston Engines," F. A. I. Muntz and P. Watson, 7.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Tues., Dec. 11.—ORDINARY MEETING: Institution of Electrical Engineers, Savoy Place, London, W.C.2, "The Independent T.V. Network: Its Operation and Maintenance," C. E. Clinch and J. B. Sewter, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Dec. 7.—GLOUCESTER SECTION: Wheatstone Hall, Brunswick Road, Gloucester, Film Evening, 7.30 p.m.——EASTERN COUNTIES SECTION: Diocesan Hall, Tower Street, Ipswich, "The Use of Punched Card Methods for Production Control," J. C. Davies, 7.30 p.m.——N.E. GRADUATE SECTION: Road Way House, Oxford Street, Newcastle, "Some Problems in the Mass Production of Glass Ware," J. F. Stirling, 7 p.m.

Mon., Dec. 10.—DONCASTER SECTION: Danum Hotel, Doncaster, "Glass Reinforced Polyester Resins," H. L. Riley, 7 p.m.——SHEFFIELD SECTION: Grand Hotel, Sheffield, "Automatic Welding Developments," R. L. Swan, 7.15 p.m.——YORKSHIRE SECTION: Hotel Metropole, Leeds, "Noise and Vibration in Machinery," A. J. King, 7 p.m.

Wed., Dec. 12.—LONDON GRADUATE SECTION: 10, Chesterfield Street, London, W.1, "Work Study and Production," A. T. Seville, 7.15 p.m.——HALIFAX SECTION: White Swan Hotel, Halifax, "Applications of Drilling Machines," W. A. Hannaby, 7.15 p.m.——DUNDEE SECTION: New Imperial Hotel, 15, Tally Street, Dundee, "Some Aspects of Motion Study for Light Industry," D. Irvine, 7.30 p.m.

Thurs., Dec. 13.—LEICESTER SECTION: N. Corah (St. Margaret), Ltd., St. Margaret's Works, Leicester, "Training New Operators," F. Baxter, 7 p.m.——LINCOLN SECTION: Ruston Club, Lincoln, "Automation," A. E. Cowlishaw, 7.30 p.m.

Fri., Dec. 14.—W. WALES SECTION: Central Library, Alexandra Road, Swansea, Films of Automatically Controlled Machines, 7.30 p.m.

INSTITUTION OF PUBLIC HEALTH ENGINEERS

Thurs., Dec. 13.—Caxton Hall, Westminster, London, S.W.1, "The Architect's View of Public Health Engineering Services," F. G. Frizzell, 6 p.m.

INSTITUTION OF THE RUBBER INDUSTRY

Mon., Dec. 10.—LEICESTER SECTION: Bell Hotel, Leicester, "The Effect of Ozone on Rubber," M. Braden, 7.30 p.m.——MERSEYSIDE SECTION: Passenger Transport Office, 24, Hatton Garden, Liverpool, "Work Study," L. V. Green, 7.15 p.m.——MIDLAND SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Dunlop Cornering Force Machine," V. E. Gough and G. B. Roberts, 6.45 p.m.

Tues., Dec. 11.—SCOTTISH SECTION: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Conveyor Belting Research," J. T. Barclay, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

To-day, Dec. 7.—MIDLAND COUNTIES GRADUATES' AND STUDENTS' SECTION: Exchange and Engineering Centre, Stephenson Place, Birmingham, "Some Structural Aspects of Nuclear Reactors," W. H. Chilton, 6.30 p.m.——S.W. COUNTIES BRANCH: Duke of Cornwall Hotel, Plymouth, "Plymouth Breakwater Review," T. W. Riley, 6 p.m.——W. COUNTIES BRANCH: The University, Bristol, "Some Structures Involving Unusual Design Problems," C. E. Saunders, 6 p.m.

Mon., Dec. 10.—LONDON GRADUATES' AND STUDENTS' SECTION: 11, Upper Belgrave Street, London, S.W.1, "The Use of Precast Concrete," J. C. Maxwell-Cook, 6.30 p.m.

Tues., Dec. 11.—MIDLAND COUNTIES BRANCH: Midland Institute, Birmingham, "Design and Construction of Two Dock Sheds at Huskisson Docks, Liverpool," A. T. Clarke, 6 p.m.——SCOTTISH BRANCH: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Plastic Design in Reinforced Concrete," W. T. Marshall, 7 p.m.

Wed., Dec. 12.—Royal Empire Society, Northumberland Avenue, London, W.C.2, "Concrete Construction in the Soviet Union," L. J. Murdock, W. J. Beckwith, D. D. Matthews and K. M. Wood, 6 p.m.

Thurs., Dec. 13.—11, Upper Belgrave Street, London, S.W.1, "The Reconstruction of the Auditorium Floor at the Royal Opera House, Covent Garden," C. H. Hockley, 6 p.m.——LANCASHIRE AND CHESHIRE BRANCH: College of Technology, Manchester, "Castellated Construction," H. Saunders, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Dec. 7.—Film Evening: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Refloating of R.M.S. 'Empress of Canada,'" 7 p.m.

Mon., Dec. 10.—SHEFFIELD AND DISTRICT SECTION: Livesey Clegg House, Sheffield, "Introduction to Armature Winding," R. A. Reeve, 7.30 p.m.——N.W. SECTION: Engineers' Club, Albert Square, Manchester, "Diesel-Electric Traction," E. T. Bostock, 7.30 p.m.

Fri., Dec. 14.—INAUGURAL MEETING: Pepys House, 14, Rochester Row, London, S.W.1, Presidential Address, "Fuel Economy and Combined Heat-Electric Generation," Bryan Donkin, 7.30 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Dec. 7.—Engineers' Club, Albert Square, Manchester, "Mechanical Handling Equipment and its Applications," F. T. Dean, 6.45 p.m.

NEWCOMEN SOCIETY

Wed., Dec. 12.—Institution of Civil Engineers, Great George Street, London, S.W.1, "William Strutt's Fire-Proof and Iron-Framed Buildings, 1793–1812," H. R. Johnson and A. W. Skempton, 5.30 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

Fri., Dec. 14.—Mining Institute, Newcastle upon Tyne, "M.V. Bergensfjord," K. Haug and N. Cârter, 6.15 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., Dec. 11.—MIDLAND COUNTIES BRANCH: Midland Institute, Paradise Street, Birmingham, "The Design and Construction of Two Dock Sheds at Huskisson Dock, Liverpool," A. T. Clarke, 6 p.m.

Wed., Dec. 12.—Royal Empire Society, Northumberland Avenue, London, W.C.2, "Concrete Construction in the Soviet Union," L. J. Murdock, W. J. Beckwith, D. D. Matthews and K. M. Wood, 6 p.m.

ROYAL AERONAUTICAL SOCIETY

To-day, Dec. 7.—GRADUATES' AND STUDENTS' SECTION: 4, Hamilton Place, London, W.1, Film Show, 7.30 p.m.

Tues., Dec. 11.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "Materials for Aircraft Structures Subjected to Kinetic Heating," A. J. Murphy, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Thurs., Dec. 13.—LAND SURVEYORS' GENERAL MEETING: 12, Great George Street, London, S.W.1, "Survey Requirements for Irrigation Projects," F. S. Hardy, 5.45 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Wed., Dec. 12.—CORROSION GROUP: 14–16, Belgrave Square, London, S.W.1, "Corrosion in the Tropics," H. R. Ambler, 6.30 p.m.

SOCIETY OF ENGINEERS

Mon., Dec. 10.—17, Victoria Street, London, S.W.1, Annual General Meeting, 5.30 p.m.

SOCIETY OF INDUSTRIAL RADIOLOGY

To-day, Dec. 7.—SCOTTISH BRANCH: Royal Technical College, Glasgow, Annual General Meeting, 7.45 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Wed., Dec. 12.—CONTROL SECTION: Manson House, Portland Place, London, W.1, "Phase-Plane Methods in Control System Design," G. D. S. Maclellan, 6.30 p.m.

Advanced Engineering Courses

Acceptance Testing of Electrical Equipment for Power Supply Systems. MANCHESTER COLLEGE OF SCIENCE AND TECHNOLOGY, Sackville Street, Manchester, 1. Course of seven lectures commencing January 21. Mondays from 7 p.m. to 9 p.m. Fee £1 10s.

Queueing Theory and Practice Course. INSTITUTE FOR ENGINEERING PRODUCTION (The University of Birmingham), "Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. January 7 to 11. Fee £30.